



Disaster Risk and Effect of Informal Insurance on Human Capital Formation in Rural Areas of Developing Countries

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Abstract “Disaster and poverty” has become one of the main topics of global development for decades. Nowadays, in the rural areas of many developing countries, farmers’ fate is still decided by natural conditions. They have little savings and little access to financial services. Obviously, they are extremely vulnerable to natural disasters like droughts, floods, typhoons and earthquakes. Many methodologies dealing with poverty in developing countries have been investigated concerning a variety of aspects. However, few of these studies focus on human capital. Recognizing the importance of human capital in agricultural activity, this paper develops a methodology to analyze the human capital formation under disaster risk in rural areas of developing countries. Taking intergenerational externalities into consideration, this paper builds a three-period overlapping generations model. It is assumed that after the occurrence of a disaster, farmers are forced to leave rural areas if they cannot get enough food from their harvest to survive. In rural areas where no insurance is provided by the financial sector, farmers need to identify economic means to support themselves and their families after a disaster. Thus, they need to seek informal insurance. In order to understand the effect of these informal insurance mechanisms on the formation of human capital as well as migration from rural areas, Quasi-Credit contracts and saving of livestock are considered in the latter part of the paper. Findings in this paper show that farmers are exposed to the risk of migration without informal insurance and the existence of a vicious circle between low human capital and little human capital investment is confirmed. Moreover, Quasi-Credit contracts could prevent large-scale migration but could reduce the incentive to invest in human capital at the same time. However, within a certain range, saving of livestock may be effective to reduce migration and raise the human capital investment as well.

Key words Disaster Risk; Informal Insurance; Human Capital; Developing Countries; Overlapping Generations Model

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1. INTRODUCTION

“Disaster and poverty” has been one of the main topics of global development for decades. Especially for people whose livelihoods depend on the weather conditions, disaster is the primary cause of poverty. One notable feature of the poor is that they have little savings and little access to financial services. Since savings and loans have insurance functions, not having these makes the farmers extremely vulnerable to natural disasters. Nowadays, in rural areas of many developing countries, farmers have to feed themselves and their families with their own harvest. In years when weather conditions are favorable, most farmers can get enough food for survival. However, since monetary systems are not yet developed in these areas, people have no deposit in the bank. So, if they fail to get enough food after a disaster, they are under threat of starvation. In this case, they have to move to the urban areas and work there as unskilled labor with low wages in order to make a living.

In spite of the fact that agriculture is vulnerable to disaster and that rural-urban migration has become a common social phenomenon in developing countries, large-scale migration has not been observed as a consequence of disaster. Therefore, the hypothesis holds that informal insurance plays an important role in preventing the outflow of rural population. For example, it is very common that households in the same community help each other by providing interest-free loans or labor. It is the idea “I help you today because I expect you to help me tomorrow” (Posner, R. A. 1980) that makes such kind of tacit agreement possible. This system is called “Quasi-Credit” by Platteau and Abraham (1987). The buying and selling of livestock is another informal insurance mechanism. If the harvest is good enough, households tend to keep some livestock. In case of bad years, they can still survive a poor harvest by selling or eating the livestock. In this way, households are able to share the risks intertemporally. The two mechanisms above are playing a role of risk sharing but neither of them is provided formally. In this sense, they are called “Informal Insurance”. Obviously, various kinds of informal insurance have restrained migration after disasters effectively. However, it might have some negative effects on the development of rural communities as well. Concretely, farmers may be satisfied with their current situations, and thus, may be less motivated to make technological developments or breed improvements.

Many methodologies dealing with such kind of mechanisms in developing countries have been investigated concerning various aspects. Devereux (2001) argues that keeping livestock and mutual help are special kinds of insurance mechanisms to deal with the vulnerability and uncertainty of agricultural production. He also points out these spontaneous countermeasures may lower the efficiency of agricultural production. Platteau and Abraham (1987) analyze the characteristics and functions of Quasi-Credit contracts. Kurosaki and Sawada (1999) prove that mutual insurance plays an important role in smoothing consumption in rural areas in developing countries through an empirical study in Pakistan. As they point out, mutual insurance does help with idiosyncratic shocks within the community but does not help with collective shocks. In addition, Vidal (1997) discusses the impact that migration has on formation of human capital. Vidal proposes that human capital level is determined by human investment of individuals and is influenced by intergenerational externalities. Human investment such as education and training about agriculture is analyzed by Alam (2009) and Rodgers (1994). Moreover, Huffman (2001) points out that analysis of development of rural areas focusing on human investment should be based on a three-period model.

Although the existence of informal insurance in rural areas is confirmed in previous empirical research, its relation with development and migration has not been discussed. This research aims to analyze the effect of informal insurance on formation of human capital and migration. In this study, Quasi-Credit and livestock are considered as informal insurance which are used in rural communities as countermeasures to natural disasters and poor harvest. Human capital is considered as the productivity of agricultural

production, which is an indicator of rural society. This study analyzes various paths of development of rural areas and the effects that informal insurance has on formation of human capital and migration. The most challenging assumption in this study is that a minimum consumption level is introduced. This means that the choice a farmer has after a disaster is not a problem of preference, but a matter of survival. Another characteristic of this study is that intergenerational externalities are taken into consideration as a key point of human capital development in developing countries. In this study, behavior of a representative household is analyzed.

This paper is organized as follows. The next chapter builds a three-period overlapping generations model to discuss the optimal behavior of a household and shows the formation of human capital when informal insurance does not exist. Chapter 3 and 4 analyze the optimal behavior of a household when Quasi-Credit or livestock exists, and thus make the role of informal insurance clear. The last chapter concludes the main findings of this study.

2. HUMAN CAPITAL GROWTH WITHOUT INFORMAL INSURANCE

2.1. The Assumptions

Think about a typical household living in a rural area. This household may consist of grandparents, parents and children. To simplify, we assume that there are three generations: a grandfather, father and son. The interactions between generations are considered by using a three-period overlapping generations model. In the model, individuals live for three periods. In the 1st period of life, they are referred to as the Young. In the 2nd period of life, they are referred to as the Adult. And in the 3rd period of life, they are referred to as the Old. In the 1st period, individuals learn agricultural skills and knowledge by actually helping their parents with the farming activity. This builds human capital. The effort to learn, which usually means a decrease in leisure time for hard work, is called human investment, z_t . The subscript t means the individual is the t th generation. According to z_t , individual's human capital is formed as follows,

$$h_t = 1 + h_{t-1}^\beta z_t^\alpha \quad (0 < \alpha < 1, 0 < \beta < 1). \quad (1)$$

The equation indicates that the human capital of generation t is influenced by the human capital of the previous generation, which exactly shows the intergenerational externalities (Vidal, 1997). The overlapping generations model is a dynamic model with generality. The intergenerational externalities are essential factors in the development of rural areas. We assume that the basic human capital, when no effort is invested, is 1. This is because an individual is able to do the agricultural production to some extent even without specific skills or knowledge. This kind of productivity such as labor is described as the basic level of human capital in this model. Note that α and β represents the effect of human investment and the intergenerational externalities, respectively. When an individual moves to an urban area, he brings his son with him and leaves his father in the rural area. Thus the inheritance of agricultural technique is terminated.

The agricultural production function is defined as the product of land size and human capital. For a household, land size is fixed to 1, and human capital h_t of an individual who is in his 2nd period is applied to production. Disaster θ may bring a decrease in the harvest. Therefore, the eventual harvest of an individual after disaster is given as $h_t \cdot 1 - \theta$. Here, we assume that all the other members in the family gain equal amount of harvest, since the results would not change even if the way of division is changed. Disaster θ is a random viable in range $[0,1]$, and follows a uniform distribution $f(\theta) = 1(0 \leq \theta \leq 1)$. It is

also assumed for simplicity that individuals are perfectly selfish and the parent has no altruistic preference to his son.

Utility is used to measure the welfare of an individual. By consuming the harvest, an individual gets a positive utility equal to the difference between harvest $h_t \cdot 1 - \theta$ and minimum consumption. Minimum consumption means the lowest level of consumption for survival. For individuals who are in their 1st and 2nd period, the minimum consumption is 1 unit. Utility at minimum consumption is normalized to 0, and any consumption over the minimum could generate a positive utility. In addition, since neither study nor work is carried out and less energy is consumed in the 3rd period of life, the minimum consumption in the 3rd period is thought to be 0. If an individual moved out, he is supposed to work as an unskilled worker in an urban area and only a small amount of wage equal to the minimum consumption level is obtained. Therefore, the utility at this time is equal to 0. On the other hand, human investment, i.e., efforts, will bring a disutility, called the cost of human investment. Since human investment shows the effort an individual makes and not a consumption of harvest, it is necessary to separate it from the utility gained from the harvest. Therefore, the utility for an individual is the sum of the utility and the disutility. Moreover, households are supposed to be risk-neutral.

It is assumed that an individual has a 2-period planning horizon and is able to make his decision according to his current and next period's state. That is, an individual can consider one step further but only one. Therefore, the discount factor is 1 for the next period and 0 for the two periods later. In this chapter, since an individual's decision-making problem poses only a human investment problem of the 1st period, the calculation related to the 3rd period is not performed. In Chapter 4, the case considering the 3rd period is treated.

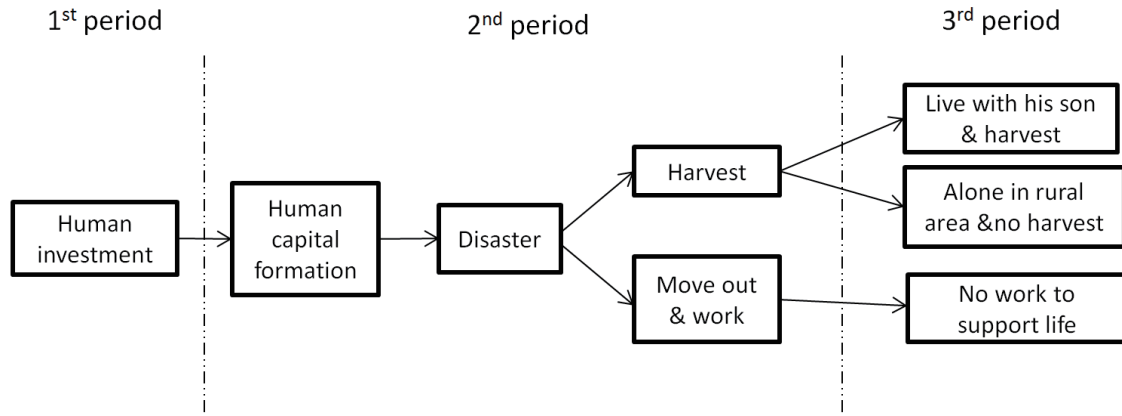


Figure 1. Sequence of events

The sequence of events is shown in Fig. 1. We assume that information on disaster risk is available to the public in advance. During the 1st period, an individual determines his human investment level, taking risks into consideration. Human capital is formed at the beginning of the 2nd period, and a disaster occurs after that. Then, harvest can be estimated according to the value of h_t and θ . The only requirement for an individual to remain in a rural area is that the harvest is greater than the minimum consumption level. Therefore, when the estimated harvest is more than 1, an individual stays in the rural areas. Otherwise, instead of harvesting, he has to move out to an urban area accompanied by his son. If the individual manages to harvest and remains in the rural area in the 2nd period, he turns agricultural production over to his son in the 3rd period. In this period, the utility of an individual depends on the harvest of his son. If his son can harvest after disaster, the individual gets $h_{t+1} \cdot 1 - \theta$ for consumption. However, if his son fails to harvest and moves out, the individual is left alone with no consumption and 0 utility. On the other

hand, for those who move out in their 2nd period, the consumption and utility in the 3rd period can be assumed to be 0, since they are not able to work physically.

2.2. The Accumulation Path of Human Capital

First, think about the response to a disaster in the 2nd period. When the disaster of θ actually occurs, the response of the Adult is as follows,

$$\begin{aligned} h_t - \theta \geq 1 &\Leftrightarrow \theta \leq \tilde{\theta}(h_t) := h_t - 1 \Rightarrow \text{Stay} \\ \theta > \tilde{\theta}(h_t) &\Rightarrow \text{Leave} \end{aligned} \quad (2)$$

$\tilde{\theta}(h_t)$ is called critical disaster level. A critical disaster level serves as a function of human-capital level. The household's response is shown in Fig. 2. In Fig. 2, the height of the shaded segment expresses an individual's utility of consumption in his 2nd period after each θ . From the assumption of the uniform distribution of θ , the area of the shaded segment expresses the expected utility of consumption when human capital is h_t . If h_t is larger than 2, the individual can remain in the rural area for sure, as shown in Fig. 2(b).

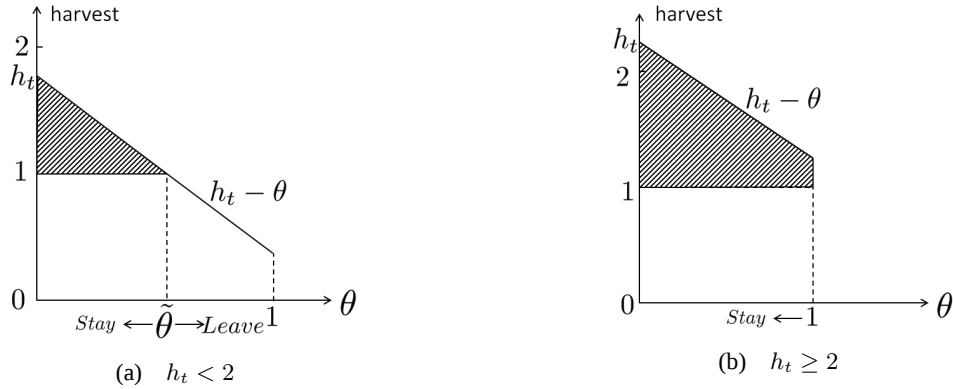


Figure 2. Relation between disaster and harvest

Now, consider the decision-making problem in the 1st period. The 1st period is the time to determine human investment according to disaster risks. The expense of human investment z_t is assumed to be z_t^2 . Here, it is necessary to consider two cases, $h_t < 2$ and $h_t \geq 2$, separately. Note that the utility of the 3rd period is not considered because of the assumption of a 2-period planning horizon.

1) $h_t < 2$

$$\max_{z_t} EU = \int_0^{\tilde{\theta}(h_t)} (h_t - \theta - 1) \cdot f(\theta) d\theta - z_t^2, \quad (3)$$

where $h_t = h_t(z_t)$ satisfies Equation (1).

Solving the first order condition, we get the optimal human investment

$$z_t^*(h_{t-1}) = \left(\frac{\alpha}{2}\right)^{\frac{1}{2-2\alpha}} h_{t-1}^{\frac{\beta}{1-\alpha}}, \quad (4)$$

which is a function of the human capital of the previous generation. Substituting the optimal human investment $z_t^*(h_{t-1})$ into Equation (1) yields

$$h_t^*(h_{t-1}) = 1 + h_{t-1}^\beta z_t^*(h_{t-1})^\alpha = 1 + \left(\frac{\alpha}{2}\right)^{\frac{\alpha}{2-\alpha}} h_{t-1}^{\frac{\beta}{2-\alpha}}, \quad (5)$$

which is also a function of the human capital of the previous generation. As long as the individual behaves rationally, $z_t^*(h_{t-1})$ and $h_t^*(h_{t-1})$ have unique solutions for any h_{t-1} . Note that $h_t^*(h_{t-1})$ might be either a convex function or a concave function of h_{t-1} .

$$\begin{aligned} \frac{\beta}{1-\alpha} > 1 &\Leftrightarrow \alpha + \beta > 1 \Rightarrow \text{convex function} \\ \alpha + \beta &\leq 1 \Rightarrow \text{concave function} \end{aligned} \quad (6)$$

In other words, if the sum of the effect of the human investment α and the impact of the intergenerational externalities β is larger(or smaller) than 1, $h_t^*(h_{t-1})$ is a convex(or concave) function of h_{t-1} .

2) $h_t \geq 2$

$$\max_{z_t} EU = \int_0^1 (h_t - \theta - 1) \cdot f(\theta) d\theta - z_t^2, \quad (7)$$

where $h_t = h_t(z_t)$ satisfies Equation (1). Equation (7) has a wider integration range than Equation (3). This means that when $h_t \geq 2$, the marginal utility of the human investment is larger than that in the previous case.

Solving the first order condition, we get the optimal human investment

$$z_t^*(h_{t-1}) = \left(\frac{\alpha}{2}\right)^{\frac{1}{2-\alpha}} h_{t-1}^{\frac{\beta}{2-\alpha}}, \quad (8)$$

which is a function of the human capital of the previous generation. Substituting the optimal human investment $z_t^*(h_{t-1})$ into Equation (1) yields

$$h_t^*(h_{t-1}) = 1 + h_{t-1}^\beta z_t^*(h_{t-1})^\alpha = 1 + \left(\frac{\alpha}{2}\right)^{\frac{\alpha}{2-\alpha}} h_{t-1}^{\frac{2\beta}{2-\alpha}}, \quad (9)$$

which is also a function of the human capital of the previous generation. As long as the individual behaves rationally, $z_t^*(h_{t-1})$ and $h_t^*(h_{t-1})$ have unique solutions for any h_{t-1} . Note that $h_t^*(h_{t-1})$ might be either a convex function or a concave function of h_{t-1} .

$$\begin{aligned} \frac{2\beta}{2-\alpha} > 1 &\Leftrightarrow \alpha + 2\beta > 2 \Rightarrow \text{convex function} \\ \alpha + 2\beta &\leq 2 \Rightarrow \text{concave function} \end{aligned} \quad (10)$$

In other words, if the sum of the effect of the human investment α and twice of the impact of the intergenerational externalities β is larger(or smaller) than 2, $h_t^*(h_{t-1})$ is a convex (or concave) function of h_{t-1} .

Comparing 1) with 2), it is easy to find that optimal human investment is in different forms in these two cases as shown in Equation (4) and Equation (8). The difference in the integration range of the expected utility is thought to be the reason. More specifically, in the case that $h_t \geq 2$, an increase in

human investment will improve the utility after disaster of any scale, while in the case that $h_t < 2$, an increase in human investment will not improve the utility if the disaster exceeds the critical disaster level $\tilde{\theta}(h_t)$.

According to Equation (6) and Equation (10), the accumulation path of the human capital h_t can be drawn as shown in Fig. 3, Fig. 4 and Fig. 5. The accumulation path for $h_t < 2$ is expressed in red, and $h_t \geq 2$ is in blue, respectively. Moreover, "•" and "o" are used to distinguish the stable and the unstable equilibrium points at the intersection with the 45 degree line. At the stable equilibrium point, since $h_t = h_{t-1}$, the human capital goes into a steady state and is constant for all generations.

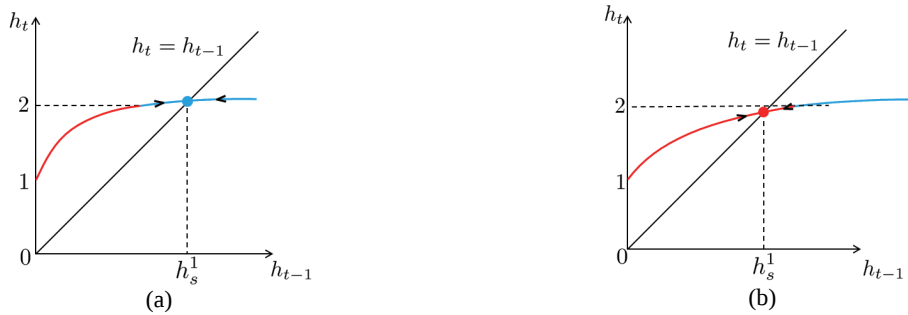


Figure 3. Human capital accumulation (Case1: $\alpha + \beta < 1$, $\alpha + 2\beta < 2$)

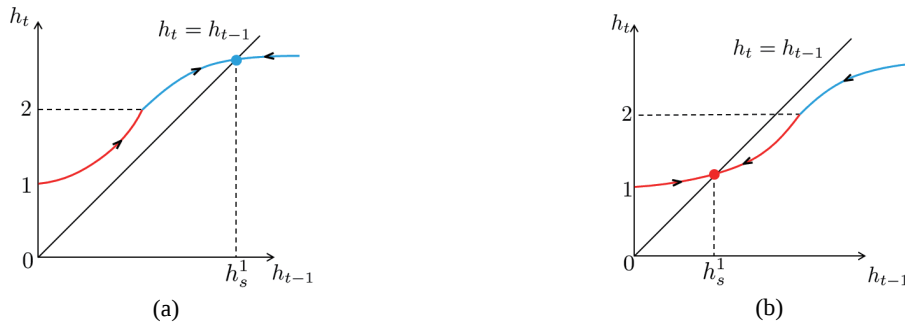


Figure 4. Human capital accumulation (Case2: $\alpha + \beta > 1$, $\alpha + 2\beta < 2$)

In Case1 ($\alpha + \beta < 1$, $\alpha + 2\beta < 2$), both (a) and (b) have one stable equilibrium point. The equilibrium point of (a) is in the range of $h_t > 2$. This is a stable state where an individual can remain in a rural area even if a disaster of the greatest scale occurs. Therefore, this point is called "a resilient stable state." On the other hand, the equilibrium point of (b) is in the range of $h_t < 2$. In this state, an individual is always exposed to the risk of having to move if a large scale disaster occurs. So, this point is called "a vulnerable stable state." In this case, even if the human capital is higher than the equilibrium state at first, h_s^1 will be reached as time passes. Especially in (b), the human capital will finally converge to the vulnerable level finally.

In Case2 ($\alpha + \beta < 1$, $\alpha + 2\beta > 2$), the human capital will converge to a resilient stable state in (a) and to a vulnerable stable state in (b), which is the same as in case1.

In Case3 ($\alpha + \beta > 1$, $\alpha + 2\beta > 2$), five different graphs can be drawn according to the value of α and β . In (a), human capital continues growing regardless of the initial level, since the path has no intersection with the 45 degree line. In (b), one resilient equilibrium point exists and we can interpret it as we do for Case1 (a) and Case2 (a). In (c), two resilient equilibrium points arise; h_s^1 which is at a lower level is stable, and the high-level one, h_s^2 , is unstable. Although the household exceeding h_s^2 can theoretically continue developing, h_s^2 is too large to be reached. (In numerical computing h_s^2 exceeds 1000 which is definitely immense compared with the assumption that disaster risk is no more than 1.) Therefore, the

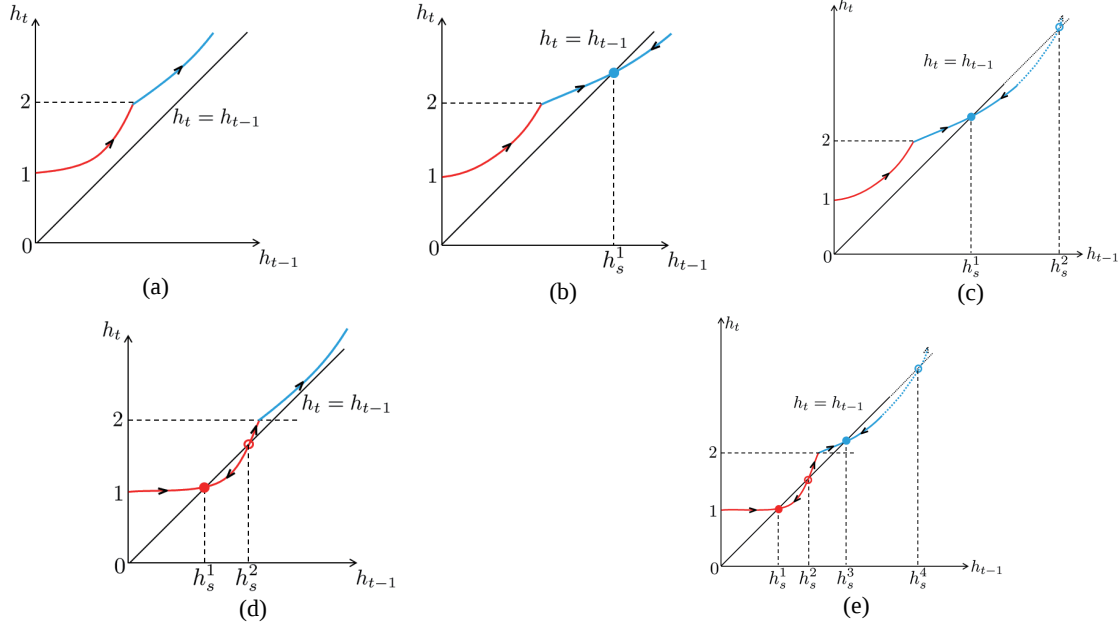


Figure 5. Human capital accumulation (Case3: $\alpha + \beta > 1$, $\alpha + 2\beta > 2$)

path in (c) is actually not different with that in (b). (d) is the opposite of (c). Two vulnerable equilibrium points exist; h_s^1 of the lower level is stable, and the high-level h_s^2 is unstable. If the human capital is more than h_s^2 , it continues growing. On the other hand, if the starting human capital is between h_s^1 and h_s^2 , it will decline gradually and converge to h_s^1 . This means that the gap expands from the initial state. In (e), the situation is a bit complicated. We can get two vulnerable equilibrium points (h_s^1, h_s^2) and two resilient equilibrium points (h_s^3, h_s^4). h_s^1 and h_s^3 are stable, while h_s^2 and h_s^4 are unstable. As explained in (c), although the household exceeding h_s^4 can theoretically continue developing, h_s^4 is too large to be reached. Therefore, the range beyond h_s^4 is out of our concern. In this case, continuous growth is not possible even for the households starting from a comparatively high level, and h_s^3 is the maximum level of human capital. As time passes, a vulnerable group with a low human capital level and a resilient group with a high human capital level will emerge. Thus the rural society will become bipolarized. Although the existence of accumulation paths other than those above cannot be denied, it was not observed in the numerical computation that was performed within the range of the parameters in this model.

2.3. Influence of a Disaster

After a disaster $\hat{\theta}$ ($0 < \hat{\theta} < 1$) occurs, it is the level of human capital that determines whether an individual can stay or leave. The following equations show how a household's response to a disaster depends on its human capital.

$$\begin{aligned} h_t - \hat{\theta} \geq 1 &\Leftrightarrow h_t \geq \hat{h}_t(\hat{\theta}) := 1 + \hat{\theta} \Rightarrow \text{Stay} \\ h_t < \hat{h}_t(\hat{\theta}) &\Rightarrow \text{Leave} \end{aligned} \quad (11)$$

$\hat{h}_t(\hat{\theta})$ is called the critical human capital level for $\hat{\theta}$. If a disaster never occurs, we always have $h_t > 1$, so migration is not going to happen. However, households may move out because of damage due to the

disaster. If we expand a representative household to a rural area, we get some indications from Fig. 6. A rural area with a vulnerable stable state $h_t < 2$ is always exposed to the risk of depopulation after a large-scale disaster. A rural area with the potential to reach the resilient stable state $h_t > 2$ may also suffer depopulation if a serious disaster happens during its development.

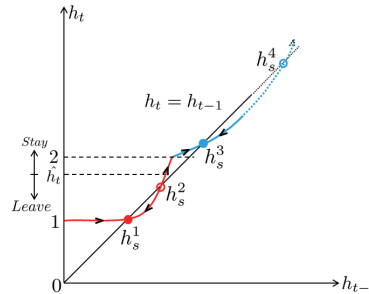


Figure 6. migration caused by disaster

2.4. Comparative Dynamics

As discussed in 2.2, the growth paths of human capital take different forms as the effect of human investment α and the impact of intergenerational externalities β change. In this section, we will mainly analyze how the value of β changes the growth path of human capital and how the human capital of previous generation h_{t-1} influences the behavior of the current generation.

The greater β is, the greater impact h_{t-1} has on human capital formation. Will greater impact of h_{t-1} bring more investment on human investment z_t ? We differentiate Equation (4) and Equation (8) with respect to β . Since $\frac{\partial z_t^*}{\partial \beta} > 0$ is always true, z_t is an increasing function of β , meaning that an individual tends to invest more if the impact of intergenerational externalities is greater. We can investigate the relation between β and h_t in the same way. We differentiate Equation (5) and Equation (9) with respect to β , and get $\frac{\partial h_t^*}{\partial \beta} > 0$. Therefore, h_t is an increasing function of β , meaning that a higher level of human capital is formed when the impact of intergenerational externalities is greater.

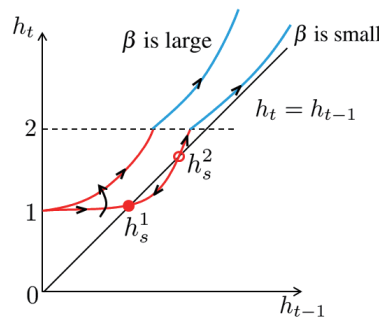


Figure 7. β and human capital accumulation

Fig. 7 shows how the growth path changes if the level of β becomes larger. If β is larger, the curve $h_t^*(h_{t-1})$ shifts upwards, and the vulnerable equilibrium point may disappear. Moreover, when disaster $\hat{\theta}$ happens, a lower h_{t-1} is required to reach the critical human capital level $\hat{h}_t(\hat{\theta})$. These changes will make a rural area more resilient to disaster. Therefore, measures that enlarge β , such as improvement in parents's teaching of agricultural technology, should be taken in order to control migration from rural areas.

Futhermore, we can get $\frac{\partial z_t^*}{\partial h_{t-1}} > 0$ by differentiating Equation (4) and Equation (8) with respect to h_{t-1} . This means that the larger h_{t-1} is, the more investment is made. For households with larger h_{t-1} , although the risk of moving out is low enough, they are still willing to make more investment than households with smaller h_{t-1} . This is because they want to make full use of the advantage of higher marginal productivity.

3. THE EFFECT OF QUASI-CREDIT ON HUMAN CAPITAL FORMATION

3.1. Assumptions of the Quasi-Credit Model

Quasi-Credit Contract is a mechanism by which farmers help each other mutually. In this way, it plays a role as insurance and exists in rural areas in developing countries universally. The greatest feature of Quasi-Credit is that help and loans are provided free of interest. By helping others in favorable years and getting help in poor years, households are able to realize consumption stabilization. There are many types of Quasi-Credit. In some cases, there is borrowing and returning in such kind of contract. However, in this model the Quasi-Credit means the sharing of risk instead of the real lending and borrowing mechanism.

Suppose two households from the same community make a Quasi-Credit Contract. The two households have human capital of the same level. Disaster events for them are supposed to be independent for simplification. That is, the disaster risk for two households θ_1 and θ_2 are following the same distribution and independent with each other. Therefore, the harvest of two households is different after disaster. According to the Quasi-Credit contract, they share their harvest equally and have the same consumption. However, if the total harvest is not enough for both households to stay, the best strategy is that one household remains in the rural area while the other household moves to an urban area. We suppose the household who gets more harvest remains and gets harvest from the other household. In this contract, a household whose harvest is more than the minimum consumption can remain for sure regardless of the harvest of the other household. Since the household with less harvest has to leave before the harvest season, it is reasonable to assume that the other household take over all the remaining harvest.

When Quasi-Credit exists, the decision to stay or leave is made according to the harvest of both households. Table.1 shows the decision of the household when Quasi-Credit is introduced. Note that harvest in this table denotes the quantity per capita, and total harvest of a household is 3 times the amount.

Table 1. Harvest and utility of consumption under Quasi-Credit

	Harvest	Decision	Utility of consumption
I	$0 \leq (h_t - \theta_1) + (h_t - \theta_2) < 1$	leave	0
		leave	0
II	$1 \leq (h_t - \theta_1) + (h_t - \theta_2) < 2$	leave	0
		stay	$2h_t - \theta_1 - \theta_2 - 1$
III	$(h_t - \theta_1) + (h_t - \theta_2) \geq 2$	stay	$\frac{2h_t - \theta_1 - \theta_2}{2} - 1$
		stay	$\frac{2h_t - \theta_1 - \theta_2}{2} - 1$

3.2. Growth Path of Human Capital and Human Investment

Since Quasi-Credit shares the disaster risk of two households completely, a new variable $\mu = \theta_1 + \theta_2$ expressing the total disaster damage of the two households should be introduced. The probability distribution of θ_1 and θ_2 follows uniform distribution as it does in the previous model, i.e. $f(\theta_1) = f(\theta_2) = 1$. Therefore, the probability density function of $g(\mu)$ can be written as follows,

$$g(\mu) = \begin{cases} \mu & (0 < \mu < 1) \\ 2 - \mu & (1 < \mu < 2) \end{cases} \quad (12)$$

In the 1st period, households determine the investment in human capital according to the total disaster risk $g(\mu)$. As mentioned above, two households are symmetrical at this point. If $h_t \geq 2$, moving out will not happen. Moreover, if $1.5 \leq h_t < 2$, at least one household may remain in the rural area. In this study, we focus on the early stages of development in rural areas, so the situation where $h_t < 1.5$ is analyzed. This means that either or both households have to move out of the rural area if a serious disaster occurs.

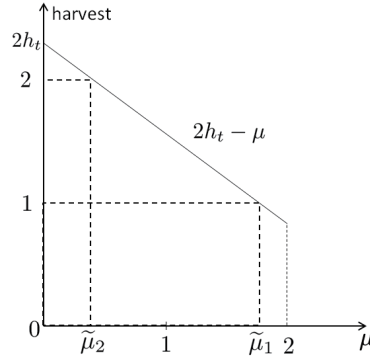


Figure 8. Relation between disaster and harvest under Quasi-Credit

The sum of the total harvest for each level of disaster is shown in Fig. 8. As shown in the figure, the critical disaster level for either household to stay is $\tilde{\mu}_1$ and the critical disaster level for both household to stay is $\tilde{\mu}_2$. For the disasters between $\tilde{\mu}_1$ and $\tilde{\mu}_2$, each household has 50 % possibility to stay and consume $2h_t - \mu$. As for disasters between $\tilde{\mu}_2$ and 0, each family can stay and consume $(2h_t - \mu)/2$ for sure. Taking these information into consideration, an individual determines the optimal human investment in the 1st period to maximize his lifetime expected utility. Therefore, the problem can be formulated as follows,

$$\max_{z_t} EU = \int_0^{\tilde{\mu}_2(h_t)} \left(\frac{2h_t - \mu}{2} - 1 \right) \cdot g(\mu) d\mu + \int_{\tilde{\mu}_2(h_t)}^{\tilde{\mu}_1(h_t)} \frac{1}{2} \cdot (2h_t - \mu - 1) \cdot g(\mu) d\mu - z_t^2. \quad (13)$$

In this chapter, numerical computation is used for the analysis. Fig. 9(a) shows the result of the case where the effect of human investment α and the intergenerational externalities β are small, and Fig. 9(b) shows the result of the case where α and β are large. The curves of the cases where Quasi-Credit does not exist in 9(a) and 9(b) take the same form of the curves in Fig. 3(b) and Fig. 5, respectively. A blue line expresses the growth path of the human capital from the model of Chapter 2 when Quasi-Credit does not exist, and the red line expresses the growth path when Quasi-Credit exists. Moreover, the green line is a 45 degree line, expressing $h_t = h_{t-1}$.

As shown in Fig. 9(a), human capital is higher when Quasi-Credit does not exist; when the effect of intergenerational externality and human investment is small. When Quasi-Credit does not exist, human

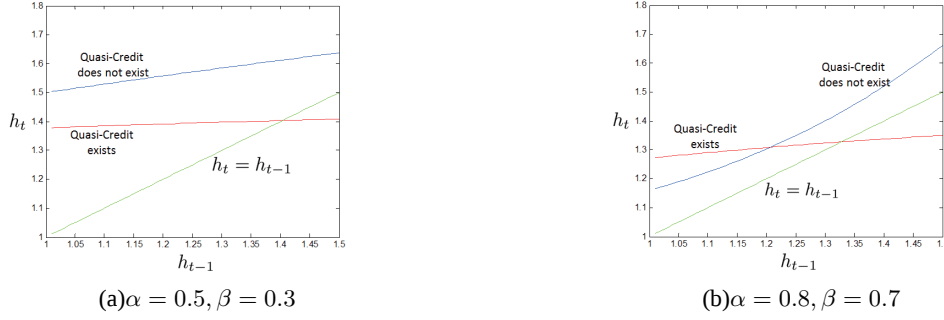


Figure 9. Human capital accumulation under Quasi-Credit ($h_t < 1.5$)

capital will continue growing without entering into a stable state in the range of $h_t < 1.5$. However, by bringing in Quasi-Credit, growth will stop in $h_t < 1.5$. On the other hand, as shown in Fig. 9(b), when the effects of intergenerational externality and human investment are large, human capital is higher than Chapter 2's model in the stages where human capital is low. However, if h_{t-1} becomes larger, this relation is reversed. Existence of Quasi-Credit brings about a stable state. Thus, growth of human capital stops at a low level.

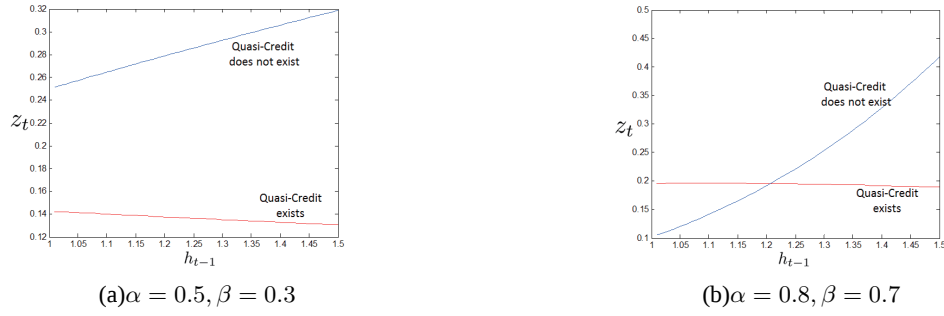


Figure 10. Human investment under Quasi-Credit ($h_t < 1.5$)

Fig. 10 is the result of numerical computation of human investment z_t . Red and blue express the cases "Quasi-Credit exists" and "Quasi-Credit does not exist", respectively. As analyzed by comparative dynamics in Chapter 2, when Quasi-Credit does not exist, z_t is an increasing function of the human capital of the previous generation h_{t-1} . However, it is just the opposite when Quasi-Credit exists. z_t is a decreasing function of h_{t-1} , meaning that when the individual feels relieved, he will stop trying hard. This can explain why the human capital in Fig. 9 does not grow. However, we can say from (b) that when h_{t-1} is less than 1.2, Quasi-Credit is an incentive for individuals to make a human investment.

Note that when parameters are large as in Fig. 9(b), human capital converges to a fixed stable state, which is different from the result we got in Chapter 2 that a continuous development in the human capital is possible. This happens as the consequence of a decrease in human investment caused by Quasi-Credit.

3.3. The Impact of Quasi-Credit on Rural Society

In order to investigate the impact of Quasi-Credit on rural society in the long term, numerical computation is carried out to see how human investment, human capital, expected utility and probability of stay

grows over time.³ We analyze two cases, the case where α and β are small, and the case where they are large.

a) The case where α and β are small ($\alpha = 0.5, \beta = 0.3$)

Fig. 11 shows the impact of Quasi-Credit when the effect of human investment α and the effect of intergenerational externalities β are small. The horizontal axis of each figure expresses how many generations passed; red line and blue line show whether Quasi-Credit is introduced or not.

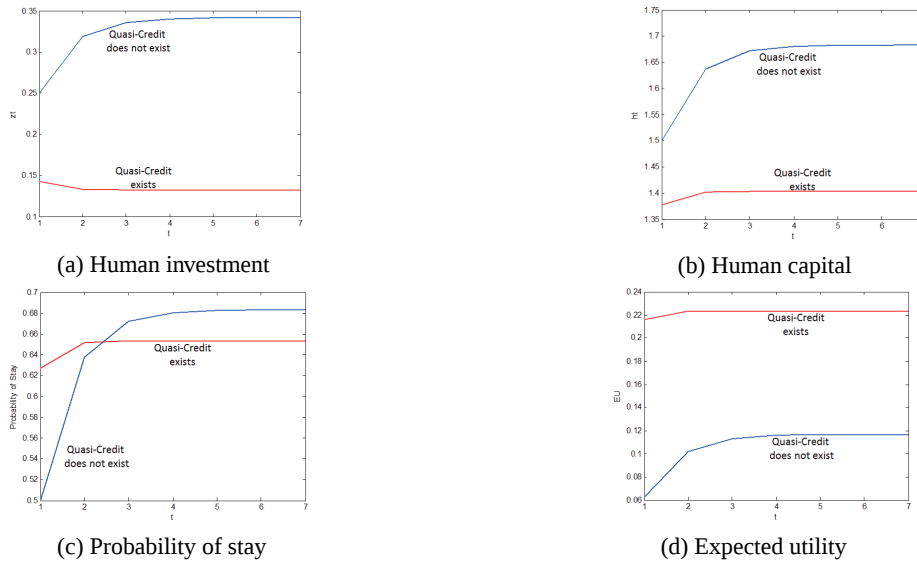


Figure 11. The influence of Quasi-Credit ($h_t < 1.5, \alpha = 0.5, \beta = 0.3$)

Human investment of each generation is compared in (a). When Quasi-Credit exists, the investment in human capital always takes a small value. So, it is obvious that by introducing Quasi-Credit, an individual becomes less willing to invest.

(b) is a figure which compares the level of human capital of each generation. Human capital in the case where Quasi-Credit does not exist is always higher than the case where it exists. This can be explained as a result of the difference in human investment shown in (a). This relation is also in accordance with the result of Fig. 9(a). Although human capital converges to a certain level no matter if Quasi-Credit exists or not, Quasi-Credit does make the final level lower. That is, the system of Quasi-Credit has a negative effect on accumulation of human capital in rural society.

(c) compares the probability that a household will stay in a rural area. When there is no Quasi-Credit, the probability of stay is equivalent to the probability that the disaster under the critical disaster level $\tilde{\theta}(h_t)$ occurs. On the other hand, the probability of stay for one household when Quasi-Credit exists is equal to the sum of the probability that the disaster under $\tilde{\mu}_2(h_t)$ occurs and half of the probability that the disaster between $\tilde{\mu}_1(h_t)$ and $\tilde{\mu}_2(h_t)$ occurs. As shown in the figure, in the early stages when human capital is small, Quasi-Credit has the effect of raising the possibility of stay. However, as time passes, the human capital grows faster when Quasi-Credit does not exist, and the probability of stay will be higher than in the case where Quasi-Credit exists. Therefore, we cannot conclude that Quasi-Credit has an effect

³The simulation here is based on the disaster risk. It is different from Monte Carlo simulation where many possible paths are simulated based on different disaster scale. It is not necessary to make the stochastic simulation because none of the human investment, human capital, probability of stay and expected utility is related to the scale of disaster that really happened. They are determined by the human capital of previous generation and the distribution of disaster risk, and are not damaged by disaster as long as the household survives in the disaster.

of preventing migration.

Finally in (d), the expected utility of each generation is compared. When evaluating the system of Quasi- Credit, the most important criteria is the expected utility showing the overall welfare of individuals. We can find from (d) that regardless of the low human capital and high probability of migration, the expected utility is raised significantly by Quasi-Credit.

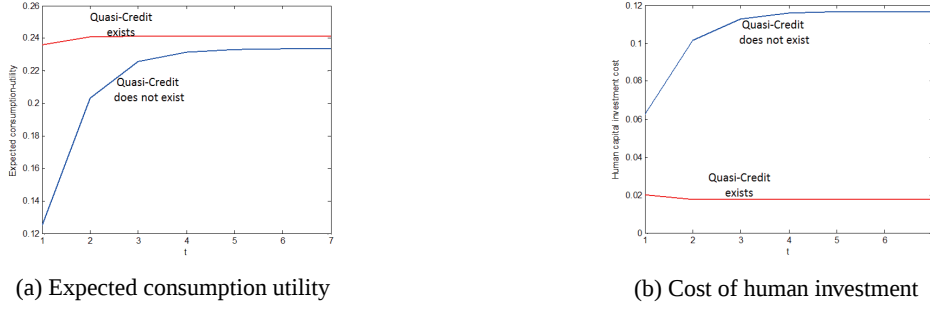


Figure 12. Two components of expected utility ($h_t < 1.5$, $\alpha = 0.5$, $\beta = 0.3$)

In order to understand how the increase in expected utility occurs, expected utility is divided into two components, the positive utility gained from consumption and the negative utility that comes from human investment. Fig. 12 shows the influence of Quasi-Credit on these two components which constitute the expected utility. First, from Fig. 12(a), we learn that the expected utility by consumption is higher in the system of Quasi-Credit, in spite of little human investment and low human capital levels. In fact, when $1 \leq 2h_t - \mu < 2$, a household has a chance to take over the harvest of the leaving household, and this definitely raises their expected utility of consumption. The increase is discontinuous and this can be explained by an easy numerical example. When the harvest of the households is $(h_t - \theta_1, h_t - \theta_2) = (1.1, 0.9)$ after disaster, both households will stay and consume $(1.1 + 0.9)/2 = 1.0$. Then, when the damage of Household 1 increases a little and the harvest becomes $(h_t - \theta_1, h_t - \theta_2) = (1.0, 0.9)$, Household 1 can consume $1.0 + 0.9 = 1.9$. In this case, Household 1 can get more consumption with a larger scale of disaster since the decrease in total harvest makes Household 2 move out and thus Household 1 can consume the harvest that Household 2 leaves behind. The advantage of Quasi- Credit is just here. If there was no Quasi-Credit, the harvest of Household 2 (0.9) will be thrown away without being consumed. However, thanks to Quasi-Credit, as long as one household can stay in a rural area, the harvest of the leaving household will be effectively consumed. Therefore, as shown in Fig. 11(c), households become more motivated to access income opportunities in urban areas when Quasi-Credit exists. Since agricultural products are less probably being thrown away, the opportunity cost of migration decreases.

Moreover, in the case when $(h_t - \theta_1, h_t - \theta_2) = (0.8, 0.7)$, if there is no Quasi- Credit, both households will have to move out and the utility will be zero. However, by Quasi- Credit, Household 1 can have a positive utility of $0.8 + 0.7 - 1 = 0.5$ in the rural area. At the same time, such a possibility lessens the incentives to get more resilient against disaster through investment in human capital. As a consequence, the growth of human capital is slowed down.

b) The case where α and β are large ($\alpha = 0.8$, $\beta = 0.7$)

Fig. 13 shows the impact of Quasi-Credit when the effect of human investment α and the effect of intergenerational externalities β are large. The red line and blue line show whether Quasi-Credit is introduced or not.

Human investment of each generation is compared in (a). While human capital gets larger when Quasi- Credit does not exist, human capital is always small when Quasi-Credit is introduced. However, for the first two generations, human capital is higher when Quasi-Credit exists. Therefore, except for the

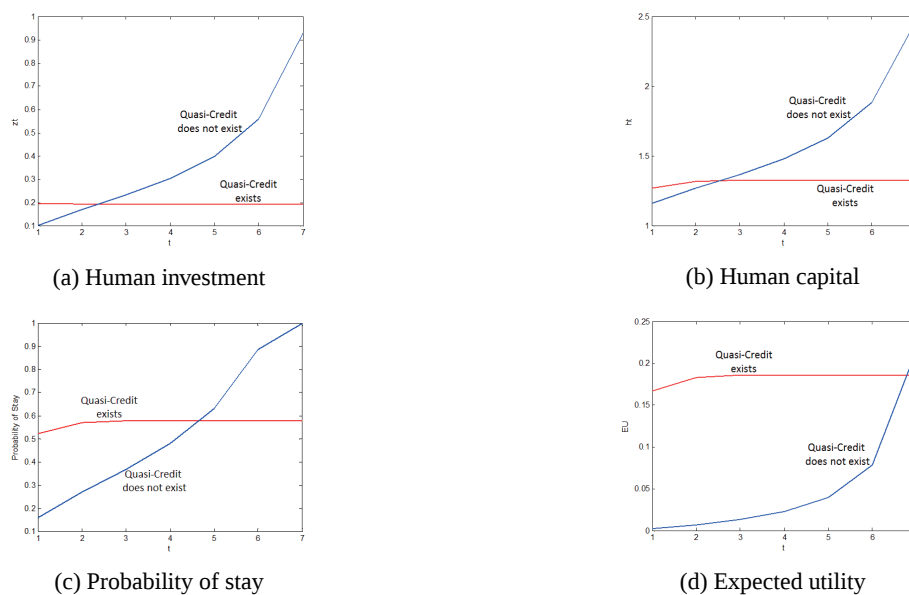


Figure 13. The influence of Quasi-Credit ($h_t < 1.5$, $\alpha = 0.8$, $\beta = 0.7$)

first several generations when the human capital level is extremely low, an individual tends to invest more in human capital when Quasi-Credit does not exist.

(b) compares human capital of each generation. As we learned from Chapter 2's model, human capital h_t is a convex function of h_{t-1} when $\alpha = 0.8$, $\beta = 0.7$. This means that accelerated development will continue without converging to a stable equilibrium. On the other hand, human capital development will reach the equilibrium within three generations, and will stop at a low level. Therefore, the system of Quasi- Credit has a negative effect on accumulation of human capital in rural society.

(c) compares the probability that a household will stay in a rural area. Similar with the result in a)($\alpha = 0.5$, $\beta = 0.3$), Quasi-Credit results in an increase in the probability of stay in the early stages. Note that in this case, there is always a possibility that a household will move out of a rural area when Quasi-Credit exists. However, the probability of leaving may decrease to 0 if Quasi-Credit does not exist, since the human capital develops rapidly and reaches a resilient human capital level.

In (d), the expected utility of each generation is compared. In contrast with the result in a) where the utility is always higher when Quasi-Credit exists, when the parameters are large, the utility of households where Quasi-Credit does not exist will grow fast and surpass the utility of households where Quasi-Credit exist as time passes. Continuous development of human capital is considered to be the determinant of high expected utility. Overall, Quasi-Credit brings up the utility in the early stages of development, but is not the desired mechanism for rural area aiming at long term development.

Fig. 14 shows the detailed influence of Quasi-Credit on expected utility. In this figure, expected utility is divided into two components, the positive utility gained from consumption and the negative utility from human investment. First, from Fig. 14(a), we learn that in the short term the expected utility by consumption is higher when Quasi-Credit exists and the opposite effect is observed as the consumption grows when Quasi-Credit does not exist. Then from Fig. 14(b), we know that the cost of human investment is also growing when Quasi-Credit does not exist. However, the effect is not as obvious as the growth in consumption utility, which results in the growth of total expected utility.

Let us summarize the result of this section. Even though the model of Quasi-Credit is formulated

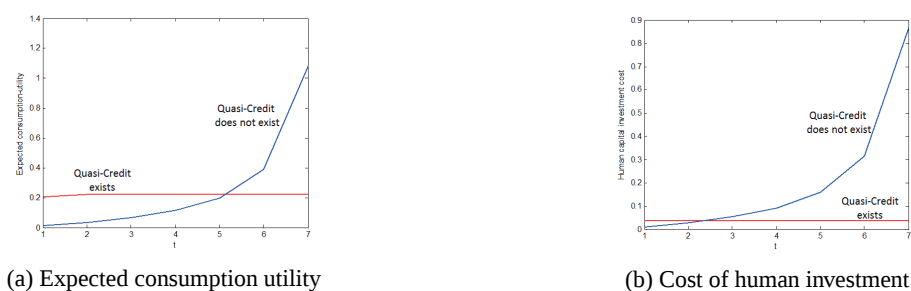


Figure 14. Two components of expected utility ($h_t < 1.5$, $\alpha = 0.8$, $\beta = 0.7$)

upon several simplifications, it has not taken in any unreal factor. In rural areas of developing countries, members of the same community keep very close relationships, and they help each other by sharing harvest. At the same time, it is also a common phenomenon that part of the family members work in cities. There are also many places where farmland and crops are managed by the whole community so that crops will not be wasted. For these communities, applying the analysis results of this section, it is easy to understand that mutual help mechanisms like Quasi-Credit has become the factor that limits growth of human capital. On the other hand, if the effect of human investment α and the intergenerational externalities β are small, households will always get a higher expected utility when Quasi-Credit is utilized. Therefore, individuals give up investing in human capital which costs a lot, and live a comparatively happy life even if the technical progress is not made.

In **b)** when the effect of human investment α and the effect of intergenerational externalities β are large, individuals live a similar life as in **a)** with the existence of Quasi-Credit. We should note that in this case, the community tends to develop continuously. When Quasi-Credit does not exist, individuals will develop human capital to a risk-resilient level and the level of expected utility will also be higher. In such an environment, the system of Quasi-Credit will make the community lose the reasons for growth. Of course, if Quasi-Credit does not exist, when a large-scale disaster occurs, all the households have to move out to the city, and the community is at the risk of disappearing. Therefore, when we discuss whether to introduce Quasi-Credit system, it is important to take the current human capital level into consideration.

In this model, the disaster risks for two households are given by independent random variables. However, it is usually thought that households in the same area should have similar disaster risks. If the correlation between the disaster risks of two households is 1, which means both households suffer the same loss and get the same harvest, the situation discussed in Chapter 2 holds. In this chapter, analysis is based on the assumption that the correlation between the disaster risks of two households is 0. Since the real correlation is neither as large as 1, nor as small as 0, we believe the reality is between these two analyses.

4. THE EFFECT OF KEEPING LIVESTOCK ON HUMAN CAPITAL FORMATION

4.1. Assumptions of the Livestock Model

Keeping livestock is a mechanism by which farmers get prepared for future disasters and smooth their consumption in different periods. In rural areas where formal financial services are not available for poor farmers, livestock is in fact the way of forming assets for them. Unlike the models in Chapter 2 and Chapter 3, the horizon of an individual is expanded to three periods in this model. When an individual makes his decision of human investment, he takes the utility of the 3rd period into consideration. It is

a custom that an individual buys M units of livestock and leaves it to the next generation if his harvest is more than $1 + M$. In this model, we focus on the human capital in rural areas where a stable state is reached. In this state, there exists a basic human capital $\bar{h}$. For each generation, $\bar{h}$ is the same, and individuals make decisions on human investment depending on whether they have livestock from the previous generations or not. Suppose the human investment is z_c when livestock is inherited, and is z_n when livestock is not inherited. Consequently, the human capital level formed is h_c and h_n , respectively. However, h_c and h_n are valid only for t th generation's production. This means that the additional human capital gained by human investment is completely depleted when the generation changes, so the $(t + 1)$ th generation has to start from basic human capital $\bar{h}$ again. As discussed in Chapter 2, if $\bar{h}$ is large enough, households will be able to stay in rural areas for sure. However, an analysis when $\bar{h}$ is relatively small is of more interest, since this is more likely to be the real situation for most developing countries.

4.2. Formulation of Livestock Model

For the t th generation, whether livestock is left to households or not is a given condition. Taking this given condition into consideration, an individual who is in his 2nd period has to choose the optimal investment to maximize his lifetime expected utility. In order to get the lifetime expected utility, we shall discuss about the expected utility of the 2nd period in 4.2.1 and the expected utility of the 3rd period in 4.2.2 respectively. Finally, the objective function for maximization is derived in 4.2.3.

4.2.1. The Expected Utility of the 2nd Period

To derive the utility of an individual in the 2nd period, two cases (when livestock is not inherited and when livestock is inherited) should be considered.

a) Livestock is not inherited

As assumed in 4.1, the basic human capital is $\bar{h}$. When livestock is not inherited, an individual's human investment is z_n and human capital h_n is formed. After disaster, his responses include the response to {Stay, Leave} and the response of {Livestock, No Livestock}. The response to {Stay, Leave} is determined in the same way as in Chapter 2's model.

$$\begin{aligned} h_n - \theta \geq 1 &\Leftrightarrow \theta \leq \tilde{\theta}_1(h_n) := h_n - 1 \Rightarrow \text{Stay} \\ \theta > \tilde{\theta}_1(h_n) &\Rightarrow \text{Leave} \end{aligned} \quad (14)$$

$\tilde{\theta}_1(h_n)$ is called the critical disaster level for stay.

If an individual managed to stay in a rural area, then his response differs depending on whether he is able to buy some livestock for the next period or not.

$$\begin{aligned} h_n - \theta \geq 1 + M &\Leftrightarrow \theta \leq \tilde{\theta}_2(h_n) := h_n - M - 1 \Rightarrow \text{Livestock} \\ \theta > \tilde{\theta}_2(h_n) &\Rightarrow \text{No Livestock} \end{aligned} \quad (15)$$

$\tilde{\theta}_2(h_n)$ is called the critical disaster level for livestock. Note the livestock M here refers to the amount of livestock per capita, so for a household, $3M$ is stocked.

According to Equation (14) and Equation (15), the relation between harvest and the responses can be shown as follows.

Thus, the expected utility of the 2nd period when livestock is not inherited can be derived as follows.

Table 2. Responses after disaster (When Livestock is not inherited)

Harvest	Response {Stay, Leave}	Response {Livestock, No Livestock}
$\theta \leq \tilde{\theta}_2(h_n)$	Stay	Livestock
$\tilde{\theta}_2(h_n) \leq \theta < \tilde{\theta}_1(h_n)$	Stay	No Livestock
$\theta > \tilde{\theta}_1(h_n)$	Leave	

$$EU2(\text{no livestock}) = \int_0^{\tilde{\theta}_2} (h_n - \theta - M - 1)d\theta + \int_{\tilde{\theta}_2}^{\tilde{\theta}_1} (h_n - \theta - 1)d\theta \quad (16)$$

b) Livestock is inherited

As assumed in 4.1, the basic human capital is $\bar{h}$. When livestock is not inherited, an individual's human investment is z_c and human capital h_c is formed. After disaster, his responses included the response to {Stay, Leave} and the response of {Livestock, No Livestock}. The response to {Stay, Leave} is determined in the same way as in Chapter 2's model.

$$\begin{aligned} h_c - \theta + M \geq 1 &\Leftrightarrow \theta \leq \tilde{\theta}_3(h_c) := h_c + M - 1 \Rightarrow \text{Stay} \\ \theta > \tilde{\theta}_3(h_c) &\Rightarrow \text{Leave} \end{aligned} \quad (17)$$

$\tilde{\theta}_3(h_c)$ is called the critical disaster level for stay when livestock is inherited.

If an individual managed to stay in a rural area, then his response differs in whether he is able to buy some livestock for the next period or not.

$$\begin{aligned} h_c - \theta + M \geq 1 + M &\Leftrightarrow \theta \leq \tilde{\theta}_4(h_c) := h_c - 1 \Rightarrow \text{Livestock} \\ \theta > \tilde{\theta}_4(h_c) &\Rightarrow \text{No Livestock} \end{aligned} \quad (18)$$

$\tilde{\theta}_4(h_c)$ is called the critical disaster level for livestock when livestock is inherited.

According to Equation (17) and Equation (18), the relation between harvest and the responses can be shown as follows.

Table 3. Responses after disaster (When Livestock is inherited)

Harvest	Response of {Stay, Leave}	Response of {Livestock, No Livestock}
$\theta \leq \tilde{\theta}_4(h_c)$	Stay	Livestock
$\tilde{\theta}_4(h_c) \leq \theta < \tilde{\theta}_3(h_c)$	Stay	No Livestock
$\theta > \tilde{\theta}_3(h_c)$	Leave	

Thus, the expected utility of the 2nd period when livestock is inherited can be derived as follows,

$$EU2(\text{livestock}) = \int_0^{\tilde{\theta}_4} (h_c - \theta - 1)d\theta + \int_{\tilde{\theta}_4}^{\tilde{\theta}_3} (h_c + M - \theta - 1)d\theta. \quad (19)$$

4.2.2. The Expected Utility of the 3rd Period

Since an individual has a 3-period planning horizon in this model, and an individual's 3rd period utility is determined by his son's harvest, it is necessary to discuss about the responses of the next generation. From the assumption that every generation inherits the same level of human capital $\bar{h}$, the responses of the $(t + 1)$ th generation is the same as the t th generation which is discussed in 4.2.1. So, the relation between the $(t + 1)$ th generation's harvest and the utility of the 3rd period for the t th generation can be shown as follows.

Table 4. Relation between responses of $(t + 1)$ th generation and utility of the 3rd period for t th generation

Livestock to the $(t + 1)$ th generation	Scale of disaster θ_{t+1}	Responses of the $(t + 1)$ th generation	Utility of the t th generation
No	$\theta_{t+1} \leq \tilde{\theta}_2(h_n)$	Stay & Livestock	$h_n - \theta_{t+1} - M$
	$\tilde{\theta}_2(h_c) \leq \theta_{t+1} < \tilde{\theta}_1(h_n)$	Stay & No Livestock	$h_n - \theta_{t+1}$
	$\theta_{t+1} > \tilde{\theta}_1(h_c)$	Leave	0
Yes	$\theta_{t+1} \leq \tilde{\theta}_4(h_c)$	Stay & Livestock	$h_c + M - \theta_{t+1} - M$
	$\tilde{\theta}_4(h_c) \leq \theta_{t+1} < \tilde{\theta}_3(h_c)$	Stay & No Livestock	$h_c + M - \theta_{t+1}$
	$\theta_{t+1} > \tilde{\theta}_3(h_c)$	Leave	$3M$

Note that if the t th generation fails to leave some livestock to the $(t + 1)$ th generation, the utility of the 3rd period becomes 0 when the $(t + 1)$ th generation moves out. However, if he manages to leave M units of livestock to the $(t + 1)$ th generation, he can get some utility from consumption of the livestock even if the $(t + 1)$ th generation moves out. And the consumption of livestock is $3M$, the total amount of livestock of the household.

From Table 4, the expected utility of the 3rd period for the t th generation can be written as follows.

$$EU3(\text{no livestock to the } (t + 1)\text{th generation}) \quad (20)$$

$$= \int_0^{\tilde{\theta}_2} (h_n - \theta_{t+1} - M)d\theta_{t+1} + \int_{\tilde{\theta}_2}^{\tilde{\theta}_1} (h_n - \theta_{t+1})d\theta_{t+1}$$

$$EU3(\text{livestock to the } (t + 1)\text{th generation}) \quad (21)$$

$$= \int_0^{\tilde{\theta}_4} (h_c - \theta_{t+1})d\theta_{t+1} + \int_{\tilde{\theta}_4}^{\tilde{\theta}_3} (h_c + M - \theta_{t+1})d\theta_{t+1} + \int_{\tilde{\theta}_3}^1 3Md\theta_{t+1}$$

4.2.3. Lifetime Expected Utility of the t th generation

Using the expected utility of the 2nd period and the expected utility of the 3rd period discussed in 4.2.1 and 4.2.2, the lifetime expected utility function of the t th generation can be derived as Equation (23) and Equation (24). From the assumption of the uniform distribution of θ , $\tilde{\theta}_2$ and $\tilde{\theta}_4$ denote the probabilities that the t th generation could keep M livestock for the $(t + 1)$ th generation, while $(\tilde{\theta}_1 - \tilde{\theta}_2)$ and $(\tilde{\theta}_3 - \tilde{\theta}_4)$ denote the probabilities that the t th generation stay in a rural area without leaving livestock to the next generation.

$$\begin{aligned} EU(\text{no livestock}) = & -z_n^2 \\ & + EU2(\text{no livestock}) \\ & + \tilde{\theta}_2 \cdot EU3(\text{livestock to the } (t + 1)\text{th generation}) \\ & + (\tilde{\theta}_1 - \tilde{\theta}_2) \cdot EU3(\text{no livestock to the } (t + 1)\text{th generation}) \end{aligned} \quad (22)$$

$$\begin{aligned} EU(\text{livestock}) = & -z_c^2 \\ & + EU2(\text{livestock}) \\ & + \tilde{\theta}_4 \cdot EU3(\text{livestock to the } (t + 1)\text{th generation}) \\ & + (\tilde{\theta}_3 - \tilde{\theta}_4) \cdot EU3(\text{no livestock to the } (t + 1)\text{th generation}) \end{aligned} \quad (23)$$

From the first-order condition

$$\frac{\partial EU(\text{no livestock})}{\partial z_n} = 0 \quad (24)$$

and

$$\frac{\partial EU(\text{livestock})}{\partial z_c} = 0, \quad (25)$$

we can obtain the value of z_n and z_c .

4.3. The Impact of Keeping Livestock

As in Chapter 3, numerical computation is also used in this chapter. Fig. 15 compares human investment and human capital of individuals who inherit livestock from the previous generation and who do not when parameters α and β are large. Changing the value of parameters, we can get Fig. 16.

In both figures, we observe that individuals tend to make more human investment and form higher human capital when they inherit livestock from previous generations. The figures also show that the higher the basic human capital is, the more human investment individuals make and the higher the human capital is. These results have some implications for raising human capital of rural area in developing countries. As shown in Fig. 15 and Fig. 16, the human capital (both h_c and h_n) depends much on the basic human capital, $\bar{h}$. Therefore, when keeping livestock is a custom of a rural area, efforts to raise basic human capital level $\bar{h}$ should be made. Such kind of effort may include sharing or keeping records of knowledge and technology of agricultural production so that individuals can start building their own human capital from a higher level.



Figure 15. Human investment and human capital based on $\bar{h}$ ($\alpha = 0.8, \beta = 0.7$)



Figure 16. Human investment and human capital based on $\bar{h}$ ($\alpha = 0.5, \beta = 0.3$)

If the basic human capital $\bar{h}$ is fixed to a certain level, it is easy to see how human investment changes according to the scale of livestock M . Fig. 17 shows the relation between human investment and the scale of livestock.¹

When α and β are large, as Fig. 17(a) shows, both individuals who inherited livestock and individuals who did not inherit livestock tend to make more human investment as the scale of livestock M becomes larger. On the other hand, when α and β are small, as Fig. 17(b) shows, for the individuals who did not inherit livestock from the previous generation, more livestock becomes the incentive for more human investment. However, the individuals who inherited livestock from the previous generation do not make more human investment when the scale of livestock becomes larger. Instead, a slight decrease in human investment can be seen from Fig. 17(b) when livestock is inherited. This implies that when the effect of human investment is less valued, individuals are less willing to make human investment and become more dependent on the livestock left to them.

5. CONCLUSION

In this paper, a 3-period overlapping generations model which considers intergenerational externality is formulated for rural areas in developing countries. Formation of human capital under natural disaster risks before and after the introduction of informal insurance mechanism is analyzed. If a catastrophic disaster occurs in the early stages of development when there is no informal insurance, many households may move out from rural areas simultaneously. On the other hand, the probability of moving out becomes smaller as human capital grows and households will be more motivated to make a human investment. The

¹Under the assumptions of this model, z_c and z_n is not constant at $M = 0$. This is caused by the different structures of decision-making. Comparing the first-order condition Equation(24) and Equation(25), we find that Equation(25) is a function of z_c while Equation(24) is a function of both z_c and z_n . In other words, the decision-making for individuals who inherited livestock is independent. However, for individuals who did not inherit livestock, decision-making depends partly on the previous one. Here, the society without livestock is not considered, so $M = 0$ does not need to be included.



Figure 17. The relation between human investment and the scale of livestock

risk of disasters and migration is in fact a factor which extends the gap between rural areas. Moreover, it is shown that to realize continuous growth in human capital, a rural area should take measures such as technical skill succession to make the intergenerational externality play a more important role in human capital formation.

When Quasi-Credit exists, the incentive of human investment decreases and human capital stops at a low level. As a result, although Quasi-Credit is a kind of informal insurance, it will bring up the probability for an individual to move out. On the other hand, it is also shown that the probability of simultaneous migration for many households will decrease after the introduction of Quasi-Credit. Therefore, although Quasi-Credit increases small-scale migration frequency, it is thought that large-scale migrations are prevented by this system. Another impact of Quasi-Credit is that consuming the harvest left by the household that moved out will enable the household that remains in a rural area to gain a higher utility in spite of the low human investment.

Moreover, in rural areas where risk of harvest is shared intertemporally by keeping livestock, livestock is not only the insurance in case of poor harvest for the next generation, but also the incentives that encourage the next generation to make more human investment. In this sense, Livestock has totally different effects on human investment from Quasi-Credit. Most of the time, it is true that the larger scale the livestock is, the more human investment is made. However, in some particular cases, say when the effect of human investment is not significant, if farmers get more livestock from their parents, they will be less motivated to make human investment.

This research proposed a methodology to analyze the effect of informal insurance on the development of rural areas regarding human capital. For simplicity, only the most important factors are taken into consideration. However, when utilized in policy discussions, it is necessary to include more factors such as altruistic behavior, incomplete information, etc. Risk-averse preference and other factors of disaster risk should also be considered in order to make the model more precise.

As for seasonal migration which is a common phenomenon in many developing countries, this model represented part of its structure. However, the process that an emigrant returns to a rural area is not modeled in this research. Modeling of resource management regarding the return of households is left for future research.

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