Study on Earthquake Indirect Economic Loss in Rural Area

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ABSTRACT: In this paper, the concise model of agricultural economic production and recovery system was established, according to the destruction characteristics by earthquake in rural area. The function forms of this model were preset based on economic theory and model parameters were calculated by boundary conditions and statistical data. Then, in accordance with the production and recovery model, the formulas for calculating the earthquake indirect economic loss in rural area were deduced. The result indicated that the direct economic loss and the recovery time are the crucial factors, which affected the earthquake indirect economic loss in rural area.

KEYWORDS: earthquake disaster, indirect economic loss, agriculture, production function, recovery time

1. INTRODUCTION

The study on earthquake economic loss is a multi-domains edge discipline, relating to earthquake engineering, structural engineering, and socioeconomics. The quantitative analysis is one of important scientific issues about earthquake disaster reduction. With the rapid economic development, the relations among various industries in different districts are getting closer and closer, and the earthquake indirect economic loss increases quickly. Therefore, the impact on regional durative economic development by earthquake disaster is more far-reaching. Although the importance of the earthquake indirect economic loss has been recognized widely, but quantitative study is still a difficult problem. Since the 1970s, many researchers have tried to analyze and measure the influence on economic, and have made some beneficial progress. At present, studies in this aspect mainly aim at industry and commerce in cities (Shinozuka, 1997; Feng, 1998; Zhong, 2001; Zhang, 2003; Lin, 2003; at al.); however, most ruinous earthquakes occurred in the village. The relative statistics indicated that, earthquakes, the magnitude of which was more than 5 occurred 56 times from 1992 to 2005 in Yunnan, and among these earthquakes 53 epicenters were located in rural areas (Zhou, 2006). Moreover, the anti-vibration capability of houses was not eligible in countryside, and the irrigation and water conservancy systems were vulnerable, so, in fact, the rural residents were the main undertakers of earthquake disasters.

In view of the insufficiency of studying on earthquake indirect economic loss in rural area, this paper discusses the influence of agricultural reproduction caused by earthquake from researching agricultural production function and consumption function. It will have a benefit to the study on earthquake disaster indirect economic loss.

2. INFLUENCE ON AGRICULTURAL PRODUCTION CAUSED BY EARTHQUAKE

Compared with other natural disasters (for example, meteorological disaster and geological disaster), the direct

impact of agricultural production caused by earthquake disaster was different. The crop was not severely affected directly by earthquake disaster with the exception of farmland destroyed by the major earthquakes. The building facilities are the main objects suffered destruction from earthquake disaster. The direct loss caused by earthquake disasters in rural area is mainly composed of residential buildings' destruction which approximately account for 80 percent of the total loss, and the destruction of irrigation and water conservancy systems is the main part of other loss (Wang, 2005). As the difference of buildings in urban and rural area, the direct economic loss proportion brought by destruction of residential buildings in cities is not great, but the earthquake indirect economic loss caused by function destruction of the economic system is growing more serious. At present, in China, complex industrial chain has not formed in most rural areas, and agricultural production mode is still unitary, therefore, the earthquake indirect economic loss in rural area caused little attention. However, as destruction of residential buildings, a part of funds used in productive investment on original plan will be transferred to repair or rebuild houses after earthquake; thereby it leads to reduce investment in agricultural production, decline of productivity. In the next place, after earthquake, some agricultural facilities such as water conservancy engineering were damaged, numbers of production tools were destroyed, and a few livestock used as production power were injured, consequently, agricultural productivity suffered a certain extent direct destruction. In addition, after the earthquake occurred, victims were extreme panicky in psychology, some people were downhearted. They were unmotivated in productive activity, even sold off the material of production, which had seriously affected agricultural production (Zhang, 2007). In short, the indirect influence of agricultural production caused by earthquake disaster is long-standing and cannot be ignored.

Since 1990, in China, whenever the devastating earthquake occurred, seismic department has promptly organized loss evaluation with the related department at the scene. Usually the loss of house destruction can be investigated carefully and valued accurately, but it is so difficult to estimate accurately the indoor property including some production tools. Therefore, this paper mainly discusses the destruction of agricultural productivity caused by earthquake from the loss of house damage. Then, it will be analyzed from agricultural production model, production function and consumption function.

3. AGRICULTURAL PRODUCTION MODEL

Under normal conditions, the total output (Y) of economic system changes along with the time (t), some times increases and some times decreases, but the general trend is gradual increase. After earthquake occurs, the system suffers the certain extent destruction, its productivity declines, and the total output decreases also. With the implementation of relief measures, production is gradually restored (Li, 2007). It is necessary that study as the periodic course of production-consumption-investment to grasp the recovery process macroscopically and establish appropriate model.

3.1. Production function

From the perspective of economics, no matter what kind of production process can be regard as the process that a group of producer goods transforms to output under the certain conditions of society, economy, technology and nature. Production function is an economic mathematical model, which describes this process based on

some presuppositions. What it expressed is the relationship between the combination of all kind of producer goods and its potential maximum output on certain technical level.

Cobb-Douglas production function was established by American mathematician Cobb and economist Douglas in the early-1930s, and it is the most famous production function. Its general form is

$$Y(K,L) = cK^{\alpha}L^{\beta} \quad (0 < \alpha < 1, 0 < \beta < 1) \tag{3.1}$$

where Y is output value, K is capital, L is labor, α is output elasticity of capital, which expresses its contribution proportion of output, β is output elasticity of labor, and coefficient c expresses the role of technological progress. Generally, coefficients (c, α, β) were obtained by statistical analysis.

Ordinarily, the sown area was considered in this production function for agriculture, and the output can be expressed as

$$Y(K,L,A) = cK^{\alpha}L^{\beta}A^{\gamma} \tag{3.2}$$

where A is sown area, and γ is output elasticity of sown area.

According to the local statistical date before the earthquake, coefficients (c, α, β, γ) can be determined with some mathematic methods such as difference, logarithm, partial derivative and so on (Zhang, 2001). The method which usually be used is transforming Eqn.3.2 to Eqn.3.3 by replacing each variable with its natural logarithm. Then, estimate the parameters using the least square method.

$$\ln Y = \ln c + \alpha \ln K + \beta \ln L + \gamma \ln A \tag{3.3}$$

In recent years, studies of agricultural production show that capital has the most important influence to the agricultural marginal output, comparing with other production elements such as labor, sown area, etc (Li, 2007; Wang, 2005; Xin, 2006; Lin, 2007; at al.). At present, the limitation of land resource restricts the sown area expanding. In addition, in the past ten years, the production elasticity of agricultural labor is very tiny in China (Liu, 2002; Wang, 2005; Lin, 2007). Considering the uncertain variation of sown area and labor in agriculture before and after earthquake, we assume that the two elements are invariable after earthquake (keep the level before earthquake). Thus, the new model used for forecasting post-earthquake agricultural output has only one variable, which is fund:

$$Y = bK^{\alpha} \tag{3.4}$$

$$b = cL_0^{\beta}A_0^{\gamma} \tag{3.5}$$

where L_0, A_0 were labor and sown area pre-earthquake.

3.2. Consumption function

Consumption function, which was proposed firstly by British economist Keynes in 1936, is the relation of consumers' spending and each kind of interdependent factor. Keynes explains consumption only using income, so his theory is called as the absolute income hypothesis. After Second World War, the western economists did in-depth studies on consumption function, and proposed some new hypotheses. The one that has simple function form and generally conforms to the actual situation is the permanent income hypothesis proposed by the famous American economist Friedman. This theory explains that people's permanent income is the primary factor that decides consumption. The permanent income, which can be expected by consumer, is stable and durative,

whereas the temporary income is non-continuous and occasional earning. The permanent income model is expressed as

$$C = C_p + C_t \tag{3.6}$$

$$X = X_p + X_t \tag{3.7}$$

$$C_p = F(X_p) \tag{3.8}$$

where C is current consumption, C_p is permanent consumption, C_t is temporary consumption, X is current income, X_p is permanent income, and X_t is temporary income. Eqn.3.8 expresses that permanent consumption depends on permanent income.

Generally, permanent income and transitory income can be calculated according to the equations as follows:

$$X_p = (X + X_{-1} + X_{-2})/3 \tag{3.9}$$

$$X_t = X - X_p \tag{3.10}$$

where X_{-1} is the income gained in the first previous period, and X_{-2} is the income gained in the second previous period. Applications of this model explain well for the relation between consumption and income of rural residents in China. A number of empirical analyses for farmers also show that the consumption connect closely with the permanent income (Duan, 2000; Yang, 2005; Guo, 2007; Tan, 2007).

3.3. Agricultural production model before and after earthquake

Figure 1 shows the agricultural production model before and after earthquake established in this paper. For the analysis convenience, assume that earthquake occurred at the end of the year, that is, the current income of farmers was not affected.

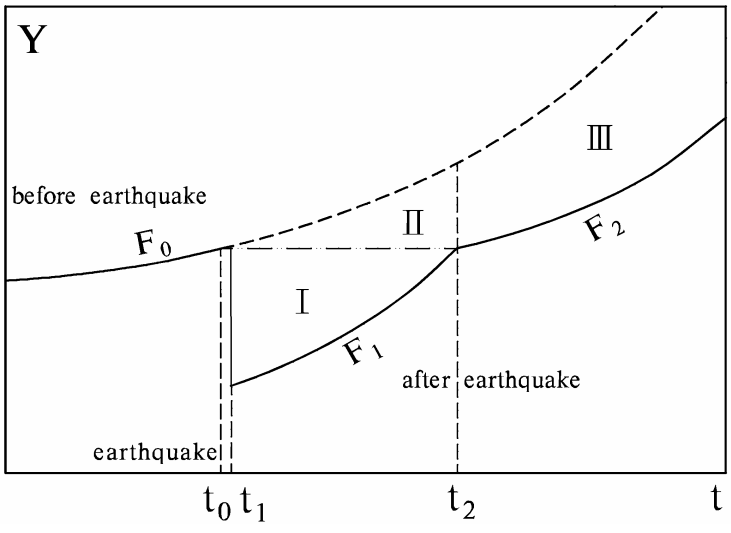

Figure 1 Agricultural production model before and after earthquake

In this model, t_0 is the year when earthquake occurred, t_1 is the next year, t2 is the year when the production gets

to the pre-earthquake level, T_r is recovery time and $T_r = t_2 - t_1$. F_0 is the function that describes the economic growth along with time before earthquake, F_1 is the economic increase function in recovery time, and F_2 is the function of economy increasing after the recovery time.

3.3.1 Determination of F_0

To determine the expression of F_0, theoretically, could first set function $K(t)$, then substitute it for K in Eqn.3.4. However, many factors affect farmers for productive investment, and it is not still clear how these factors quantitatively work on productive investment (Liu, 2002). Therefore, in well-balanced condition, it is difficult to estimate the change of productive investment. Generally, researchers presume that investment growth rate is direct proportional to the output in economic researching, that is $dK / dt = \lambda Y$. The objects of agricultural production are plants and animals, so capacity of expanded reproduction is limited for natural factors such as land, climate and so on. Therefore, this assumption does not tally with the fact of agricultural production investment in regular condition. However, according to the time series of GDP before earthquake, sets up the function $Y(t)$ that total output Y changes along with time, then could grasp the variation tendency of the total production.

3.3.2 Determination of F_1

Initialize the current income, productive investment and consumption of farmers with Y_0, K_0 and C_0, express houses destruction loss caused by the earthquake with D, rational consumers step up the property which be held in the form of houses to the per-earthquake level in t_2. Then the average annual consumption for house is D/T_r. (Assumed that the farmers' savings (S) is 0; if $0 < S < D$, replace D with (D-S); if $S \geq D$, there is not indirect economic loss.) As the current income is not decreasing in t_0, the permanent income is not affected. According to permanent income theory, the living consumption will be unchanged basically, excluding housing. So the productive investment in t_1 is

$$K_1 = K_0 - D / T_r \tag{3.11}$$

Because the total output in t_1 equal to that in t_0, the productive investments in the two years are same according to Eqn.3.4, that is $K_2 = K_0$. If K linearly increases in the period of t_1 to t_2, we have

$$K(t) = K_1 + \frac{D}{(t_2 - t_1)^2}(t - t_1) = K_0 - \frac{D}{T_r} + \frac{D}{T_r^2}(t - t_1) \tag{3.12}$$

According to Eqn.3.4, express F_1 as

$$F_1(t) = bK^{\alpha} = b[K_0 - \frac{D}{T_r} + \frac{D}{T_r^2}(t - t_1)]^{\alpha} \qquad (t_1 \leq t \leq t_2) \tag{3.13}$$

3.3.3 Determination of F_2

Researches of factors affecting agricultural productive investment show that the more production property remained last year, the more farmers invest to production; the more farmers held the house asset, the more they unwillingly invest to production (Feder, 1992; Liu, 2002). According to above analysis, the productive investment and house value of farmers are the same to t_0 and t_2. In the same other conditions, F_2 that is the

production curve after t_2 should be similar with F_0, only has a time lag.

$$F_2(t) = F_0(t - T_r) \tag{3.14}$$

3.3.4 Determination of T_r

According to the consumer theory, consumers are rational, and they will use the income on principle of effectiveness maximization. Thus, the total consumption should be equal to the gross income in recovery and reconstruction period, that is

$$\int_{t_1}^{t_2} Ydt = \int_{t_1}^{t_2} Cdt + \int_{t_1}^{t_2} Kdt \tag{3.15}$$

In Eqn.3.15, the first item on right side is living consumption, and the second is productive investment consumption. According to the permanent income theory, as current income reduction result in permanent income reduction in t_1, farmers will curtail current consumption based on permanent income level. Then the permanent income will increase gradually along with increase of current income latterly, and it will promote the consumption. According to effectiveness maximization principle, the average level of consumption in recovery and reconstruction period should be similar to pre-earthquake level. Therefore, Eqn.3.15 can be expressed as

$$\int_{t_1}^{t_2} F_1(t)dt = C_0 T_r + \int_{t_1}^{t_2} K(t)dt \tag{3.16}$$

After integral operation, there is

$$\frac{Y_0 K_0 - b(K_0 - D/T_r)^{1+\alpha}}{D(1+\alpha)} T_r^2 - (C_0 + K_0)T_r + \frac{1}{2}D = 0 \tag{3.17}$$

T_r can be solved from Eqn.3.16 by numerical method.

4. EVALUATION FOR EARTHQUAKE INDIRECT LOSS IN RURAL AREA

Figure 1 shows that the indirect economic loss *IL* is composed of three parts (Ⅰ, Ⅱ and Ⅲ). Parts Ⅰ and Ⅱ are the loss in the near future, we do not consider the influence of social discount rate; part Ⅲ is the opposite.

$$IL(\text{Ⅰ}) = \int_{t_1}^{t_2} [Y_0 - F_1(t)]dt \tag{4.1}$$

Combining Eqn.3.16 and Eqn.4.1, there is

$$IL(\text{Ⅰ}) = (Y_0 - C_0 - K_0)T_r + \frac{1}{2}D \tag{4.2}$$

The above equation indicate that if farmer's earning and expenditure are balanced in t_0, namely $Y_0 = C_0 + K_0$, loss part Ⅰ just is half of direct economic loss.

$$IL(\text{Ⅱ}) = \int_{t_1}^{t_2} (Y(t) - Y_0)dt \tag{4.3}$$

$$IL(\text{III}) = \int_{t_2}^{\infty} (Y(t) - Y(t-\Delta t))(1+i)^{t_0-t}\, dt$$
$$\approx \int_{t_2}^{\infty} (Y(t_2) - Y_0)(1+i)^{t_0-t}\, dt \tag{4.4}$$
$$= (1+i)^{(t_0-t_2)} (Y(t_2) - Y_0) / \ln(1+i)$$

$$IL = IL(\text{I}) + IL(\text{II}) + IL(\text{III}) \tag{4.5}$$

In above equations, i is social discount rate. Eqn.4.1 ~ Eqn.4.5 indicate that the direct economic loss D and the recovery time T_r are the crucial factors, which affected the earthquake indirect economic loss in rural area.

It should be pointed out that this method is only suitable for the conditions that houses were damaged partially and residents mainly relied on self-help approach to restore production. Regarding the major earthquake disaster, residents' homestead were destroyed entirely, relief and production resumption mainly depended on government. In this condition, specific analysis should be done according to government's disaster relief efforts. Because pre-earthquake production function could not be used in recovery period while materials of agricultural production were destructed severely by earthquake.

5. CONCLUDING REMARK

Earthquake disaster is the social and economic problem that was concerned widely. Because there is a long process between earthquake disaster and the indirect economic loss caused by it, and indirect economic loss is impacted by disaster's intensity, anti-destruction capacity of suffering body, disaster relief speed, etc. At present, there is not an objective and quantitative method for estimating earthquake indirect economic loss. This article discussed the quantitative method for estimating earthquake indirect economic loss in rural area, from influence on agricultural production, agricultural production model, production function, and consumption function and so on. The result indicated that the direct economic loss and the recovery time are the crucial factors, which affected the earthquake indirect economic loss in rural area. Due to the limitation of data available, we only give the discussion and analysis in theory, and the further studies on empirical confirmation are needed.

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