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Relationship between Fragmentized Collective Forestland, Farmers Investment and Forest Commodity Output: An Analysis on Nine Provinces Farmers Survey Data in China*

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Abstract. The purpose of this study is to quantify the relationship between fragmentized collective forestland, farmers investment and forest commodity output to examine the rationality of collective forest right reform after dispersed forestland operation. The data is based on the 2420 farmers' survey data in nine provinces of China including Fujian, Jiangxi, Hunan, Sichuan, Zhejiang, Guangxi, Henan, Shandong and Liaoning. The results show that if S index is used, fragmentized forestland reaches 0.41 and can be ordered (from high to low) as Zhejiang, Jiangxi, Hunan, Liaoning, Sichuan, Fujian, Guangxi and Shandong. Under certain fragmentized intervals (forestland fragmentized ratio lower than 0.22 or higher than 0.51), the higher the forestland fragmentized, the lower the farmers investment. The investment-output model indicates that forest block reflects the negative impacts to forest output while other variables such as labor, tangible inputs and forestland have positive impacts. When bamboo is produced, level of fragmentation has negative impacts on forestland acreage and significant positive impacts on labor used. The study implies that after the land is divided to households, physical investment is the key factor to affect the commodity output and should be considered by the related policies to increase the incentives of farmers. Based on this study, we provide some information and guidance on policy of farmers' forestland operation in large scale.

Key words: collective forest rights reform, fragmentized forestland, farmers' investment, forest commodity output.

1. Introduction

Forestland fragmentation is a process related to geography, population, family tradition and regulation changes. Landscape is complex in China, which provides advantageous condition for diversified forestland operation and at the same time, causes the fragmentation of natural forestland. From the historical point of view, China's population increased dramatically since Song Dynasty and land supply could not follow the speed of population boom. This is one reason for the increased forestland fragmentation. From the viewpoint of family tradition, forestland fragmentation increased due to the traditional heritage system because land must be divided for different children. From the viewpoint of forest right mechanism changes, forestland is further fragmentized due to the policy in 1980s and the collective forest right applied in 2003. In order to overcome the economic problem resulted from the small-scale business, government raised a series of policies in 2008. Debates never stop among scholars since some argue that forestland fragmentation would not enhance the operating efficiency while others argue that fragmentation of forestland is just one part of Chinese tradition because this is fair as every farmer has his own land. From the empirical side, fragmentation of forestland is not changed significantly although current collective forest reform policy releases the right of trade to farmers. So far, the studies about the large scale evaluation of forest fragmentation, farmers' contributions and forest commodity outputs under such policies are insufficient. The study uses 2420 household survey data in 18 counties among Fujian, Jiangxi, Hunan, Sichuan, Zhejiang, Guangxi, Henan, Shandong and Liaoning provinces to answer the relationship between fragmentized collective forestland, farmers investment and forest commodity output and examine the rationality of the collective forest right reform after dispersed forestland operation.

1.1 Three fundamental stages of forest fragmentation process

In China, forest fragmentation and forest fragmentation reform starts simultaneously while the former occurs mainly in the southern collective forest. The fragmentation process can be divided into three stages. The first stage happened in 1980s with a central official document announcing that forest right should be stabilized, retained mountain should be claimed and forest production responsibility should be determined, which also accelerates the speed of forest fragmentation process. Statistics from the Department of Forest indicates that until 1984, 90% forestland owners among these 9 provinces held 0.43 hm^2 on average with 0.04 hm^2 per capita. Combination of forest, specialized farmers, and forest union increased to more than 400 households (Lu, 2002). Di's 1994 study believed that "Sanding" is a process of transferring collective forest rights to farmers household. The second stage was from late 1980s to 1990s, which supports sales. Lu (2004) thought that this type of sale is to solve the existing problems such as low allocation efficiency and small scale associated with ongoing administrative land system. Through the forest sales, collective forest switches to forest farmers even further and increased the scale of forest operation. However, this does not solve the forest fragmentation. The third and last stage is to verify the forest rights. In 2003, Fujian province reformed the collective forest system including clarifying the ownership, enhancing the operation, releasing handling power and protecting beneficiary rights after the State Council announced the "decision of speeding the development of forestry". Jiangxi, Liaoning and Zhejiang provinces also reformed later. In June 2008 another official document that explicitly determined the main object to operate forestry business. Until the end of 2009, more than 100 million hm^2 forests that have been verified their ownership, which is 59.4% of total collective forest. Certified forests are more than 80 million hm^2, about 75% of total verified forests (Jia, 2009). The reform of forest right improves the diversification of ownership-operation and speeds the process of forest fragmentation (Kong, 2008).

1.2 Problems facing forest managers after forestland fragmentation

Focusing on the negative impacts brought from the forest fragmentation, many scholars criticize this situation and small scale operation from the viewpoint of scaling operation. For example, some scholars (Song et al., 1997) suggest that household corporation system in China's collective forest operation may help benefit distribution. Li (2001) suggests that to improve the disadvantageous situation of forestry, combination forest rights might be a feasible possibility. Wang (2009) points out that speeding volunteer cooperation to solve the problem of forest fragmentation becomes an emergent task. Chinese farmers believe that owning forest is one form of their personal property instead of business operation while this kind of micro business operation results in a less competitive power due to scaling effects (Li and Wang, 2003; Liu, 2000). Zeng (2009) points out that household operation system increases the risks on expected return, short-term speculation, and monopoly of land resource while Luo and Li (1999) provided evidence in Sichuan and Guangdong for these risk exposures. However, opposite opinions do exist. Gao (2007) believe that under current China' social condition, it is not a good time because forest farmers are much more willing to invest labor and capital to enhance the forest productivity since they possess all benefits. Passion brings higher net profits. She suggests that no result is valid if it can not pass the cost-benefit analysis and because forestry requires lower technology, individual is very possible to handle his or her own forest.

2. Empirical study of the relation between fragmentized collective forestland, farmers investment and forest commodity output

2.1 Intuition of forestland fragmentation and quantitative method selection

2.1.1 Definition of forestland fragmentation

Concept of land fragmentation is widely used in China. Forest fragmentation is raised based on land fragmentation but without an exact definition. Therefore, this study infers the more mature definition on crop-land fragmentation to define the forest fragmentation. Forest fragmentation has two necessary conditions including more than two separate forests and these forests should be small. Based on these conditions, forest fragmentation means a farmer must operate more than one small forests that are not adjacent. In this study, we focus on the economic analysis of the adjacent forests although possibility of transferring non-adjacent forests to adjacent and larger forests does exist. We also emphasize the economic intuition on the small blocks and scale economy, which is to enhance the return from the resource, increase income and reduce costs (Zhang and Huang, 1997; Cheng, 2001).

Based on this definition, forest fragmentation considers more on the economic side and thus should have the following two characteristics: (1) block is too small to realize the scale economy and (2) blocks can be combined through sales.

2.1.2 The measurement of forest fragmentation

There are two major methods for the measurement of forest fragmentation. One is to use single index to measure the level of fragmentation based on the number and area of blocks (Binns, 1950) and the other is to build a relatively complicate index. King and Burton (1982) constructed *S* indexes, *J* index and *I* index based on six factors including farm size, block number, block size, block shape, spatial and grain distribution of blocks.

These indexes are expressed as follow:

$$S = 1 - \frac{\sum_{i=1}^{n} \alpha_i^2}{(\sum_{i=1}^{n} \alpha_i)^2}, \quad (1)$$

$$J = \frac{\sqrt{\sum_{i=1}^{n} \alpha_i}}{\sum_{i=1}^{n} \sqrt{\alpha_i}}, \quad (2)$$

$$I = \frac{(\sum_{i=1}^{n} \alpha_i)/n}{100} \times \sum W, \quad (3)$$

where n is the block number owned by the farmer, α is the size of the block and W is the distance between blocks.

The values of *S* and *J* are between 0 and 1. When *S* is closer to 1, then the level of forest fragmentation is higher while *J* index has opposite meaning. All three indexes use block numbers and block size as important factors, but we are not able to determine which has greater impacts. In addition, *J* index cannot reflect the fact that the level of forest fragmentation should decrease when the area of larger-sized blocks increase and the area of smaller-sized blocks decrease.

Each method has advantages and disadvantages. In this study, we focus on the number and size of blocks and the distance between block and farmers' house. However, in order to provide a better measurement of the level of forest fragmentation, we also use *S* index as a supplementary.

2.2 Quantitative analysis of the level of forest fragmentation

2.2.1 Statistic description before and after forest right reform

Table 1 shows the number and changes of farmer forestland block before and after the forest right reform. Average farmer owned block increases 0.92, which is 16.12% higher than the reform has been applied. Among the research area, the number of owned blocks in Guangxi and Liaoning provinces increases the most while that in Hunan increases the least.

From Table 1 we also see that the problem of forest fragmentation did exist and the forest rights reform is to make this problem even serious.

Table 1. The change in number of farmer forestland block before and after RFPRS

Block numbers	Fujian	Guangxi	Henan	Liaoning	Shandong	Sichuan	Zhejiang	Jiangxi	Hunan	Average
Before RFPRS, block	1.83	2.13	1.38	2.25	1.13	6.31	4.06	3.87	3.02	3.35
After RFPRS, block	2.07	2.61	1.56	2.89	1.22	7.33	4.42	4.55	3.12	3.89
Change, block	0.24	0.48	0.18	0.64	0.09	1.02	0.36	0.68	0.10	0.54
Change ratio, %	13.11	22.54	13.04	28.44	7.97	16.09	8.87	17.57	3.31	16.12

Table.2 The block number of farmers' forest management on different scale

Survey range, household	Average number of Block per household, block	Operating 1~2 blocks forest land, %	Operating 3~4 blocks forest land, %	Operating 5~6 blocks forest land, %	Operating 7~10 blocks forest land, %	Operating 10 blocks and over forest land, %	Operating 20 blocks and over forest land, %
2420	4.52	36.47	27.98	16.87	13.01	4.48	1.18%
263	3	50.83	31.40	9.92	7.85	-	-

2.2.2 Analysis of the level of forest fragmentation based on 2420 farmer households

From the survey data, we see that 36.47% of farmers operate 1-2 forests, 27.98% of farmers operate 3-4 forests, 16.87% of farmers operate 5-6 forests, 13.01% of farmers operate 7-10 forests and 5.66% of farmers operate more than 10 forests *(Table 2)*. On average, each farmer operates 4.52 forests. Based on the statistic result, we see Jiangxi, Zhejiang and Sichuan have the highest farmer owned forests while Shandong has the lowest. The difference is mainly due to the landscape and time of forest rights reform.

Table 3 shows the forest block number operated by farmers. Farmer' average and forest size are largest in Shandong, which are 9.062 hm^2 and 7.487 hm^2, respectively. Farmers in other provinces also operate 2.5 hm^2 on average and the block size is greater than 0.66 hm^2. From the viewpoints of operating scale, 75% of farmers operate 1.33 to 3.33 hm^2 while 7.85% of farmers operate a forest less than 0.1 hm^2. The result indicates that after forest rights reform, scaling operation is more obvious and the block size is stable. Compare to the cropland, forestland fragmentation is not significant.

Tables 4 and 5 illustrate the forest block distribution in China and the block distribution between blocks and roads.

Table 3. The block list of forestland in the whole country and the sample provinces

Range	Average number of block per household, block	Average area per household, hm^2	Average area per block, hm^2	Maximum block, hm^2	Minimum block, hm^2
Shandong	1.220	9.062	7.487	46.667	0.013
Liaoning	2.890	5.307	1.837	20.000	0.133
Henan	1.560	0.788	0.507	5.533	0.004
Sichuan	7.330	2.549	0.676	8.333	0.003
Zhejiang	4.420	4.397	0.996	7.400	0.033
Fujian	2.070	5.193	2.507	21.667	0.107
Hunan	3.120	2.665	0.854	12.000	0.033
Jianxi	4.550	11.425	2.512	107.813	0.013
Guangxi	2.610	2.519	0.967	10.667	0.007

Table 4. The distribution of block of farmers' forest land in different scales

Range/ha	<1	20-40	40-50	50-60	60-100	>100
Percentage of average area per block, %	13.73	61.54	13.46	4.4	3.3	3.57
Percentage of average area per household, %	7.85	40.9	13.64	7.85	11.16	18.6

Table 5. The distribution of the proportion to distance between block and road

Range, meter	<100	100-500	500-1000	1000-2000	2000-3000	3000-4000	4000-5000	>5000
Percentage, %	9.22	24.25	22.24	20.64	11.82	3.81	2.41	5.61

Generally speaking, the distance between block and road should affect the efficiency of production because the longer the distance, the more time is needed to transport commodities. The longest distance in our samples is 16 km and 5.61% of block is longer than 5 km while 9.22% is shorter than 0.1 km. Distance between block and road is less than 0.5 km.

The comprehensive *S*-index describes the level of forest fragmentation even straight. In this study, the number and size of blocks and the distance between block to road increase the measurement of *S* index.

Table 6 shows that the level of China's forest fragmentation is 0.41. *S* index is highest in Zhejiang, followed by Jiangxi, Hunan, Liaoning and Sichuan. S index in Shandong is the lowest. The trial provinces (Jiangxi, Fujian, Zhejiang and Liaoning) have higher level of forest fragmentation, which indicates that the forest rights reform has impacts on forest fragmentation. In addition, the level of forest fragmentation is directly related to natural geography because the results indicate that the level of forest fragmentation in mountain is significantly higher than that in plain. Sichuan is an example.

2.3 Description of farmers' investment under forestland fragmentation

Table 7 lists the forestry investment of farmers. The results show that average investment is less than $2200 Yuan but has increased year after year. Henan, Shandong and Zhejiang have relatively large investment due to commodity needed (ie. Fruit is the major product in these provinces). Guangxi, Hunan, Sichuan and Jiangxi have smaller investment because wood is the major product.

Table 6. The degree of forest land fragmentation in the whole country and different provinces

Region	China	Shandong	Liaoning	Henan	Sichuan	Zhejiang	Fujian	Hunan	Jiangxi	Guangxi
S index	0.41	0.11	0.46	0.16	0.42	0.62	0.42	0.48	0.58	0.40

Table 7. The forestry investment of farmer's family in 9 provinces(regions)

Year	Fujian, yuan	Guangxi, yuan	Henan, yuan	Liaoning, yuan	Shandong, yuan	Sichuan, yuan	Zhejiang, yuan	Jiangxi, yuan	Hunan, yuan	Average, yuan
2003	611.8	107.74	4995.2	384.7	1452.51	565.5	1430.34	391.94	73.72	1112.61
2007	983.8	122.23	6152.1	1702.83	1866.48	735.49	2089.43	616.51	214.52	1609.27
2008	945.2	152.53	6972.5	1670.93	2145.77	737.56	2228.55	902.89	431.23	1789.57
2009	1353	184.96	8188.5	1814.06	2297.92	925.17	2969.84	1027.39	639.96	2155.64

Table 8 indicates that average farmer's investment is low compared to their total household income. Usually the ratio is less than 0.06. In other words, farmers receive small return from forestry operation because of their low investment and thus, forestry has low importance in household income. In general, investment-income ratio in Guangxi, Hunan and Jiangxi is less than 0.03.

2.4 Relationship between farmers' investment and forest fragmentation

2.4.1 Relationship between farmers' investment and the level forest fragmentation

In order to examine the relationship between farmers' investment and the level of forest fragmentation, we use the level of forest fragmentation as independent variable *(X)* and household investment as dependent variable *(IN)* to construct a single variate regression model. The samples performs a nonlinear relationship (*S* shape) and thus the model is built in the following form:

$$IN = -10831{,}68 + 181454{,}30X - \\ - 586913{,}73X^2 + 530794{,}33X^3 , \quad (4)$$

where t is -3.742 for intercept, 5.485 for X, -5.991 for X^2 and 6.249 for X^3 with R^2 is 0.705 and F value is 28.668.

From equation (4) we see the R^2 is 0.705 and thus the model has high explanatory power. The P value of constant and independent variable is 0 and this means when others held constant, independent variable X does not have significant impact between the level of forest fragmentation and farmers' investment. Getting extreme value from this equation, when the level of forest fragmentation is between 0.22 to 0.51, higher level of forest fragmentation exists and when X falls outside this range, the level of forest fragmentation is smaller and suitable for household investment.

Table 8. The proportion of forestry investment and total income in farmer's family

Year	Fujian, %	Guangxi, %	Henan, %	Liaoning, %	Shandong, %	Sichuan, %	Zhejiang, %	Jiangxi, %	Hunan, %	Average, %
2003	3.2	1.1	15.1	2.6	12.3	4.8	4.9	2.0	0.6	6.6
2007	3.5	0.8	13.6	5.9	10.8	3.6	4.5	2.0	1.0	6.1
2008	2.8	0.9	14.4	4.9	11.4	3.5	4.1	3.0	1.8	6.2
2009	3.5	0.9	14.9	4.7	9.2	3.6	5.0	2.9	2.5	6.1

2.4.2 Relationship between the level of forest fragmentation and investment-income ratio

In order to analyze the impact between the level of forest fragmentation and investment-income ratio, we use the same independent variable and use the investment-income ratio *(YI)* as dependent variable to construct a single variate regression model. The model can be expressed as:

$$YI = 164{,}082X - 620{,}435X^2 + 592{,}516X^3, \quad (5)$$

where T is 2.814 for X, -3.593 for X^2 and 3.958 for X^3. The R^2 is 0.821 and F value is 55.154.

From equation (5) we see the R^2 is 0.821 and thus the model has high explanatory power. The P value of constant and independent variable is less than 0.01 and this means when others held constant, independent variable X does have significant impact between the level of forest fragmentation and farmers' investment-income ratio. Getting extreme value from this equation, when the level of forest fragmentation is between 0.17 to 0.52, higher level of forest fragmentation exists and when X falls outside this range, the level of forest fragmentation is smaller and suitable for household investment.

2.5 Impacts of forest fragmentation and farmers' investment on forestry production

2.5.1 Selection of model variables

This study utilizes the Cobb-Douglas production function to examine the relationship between forest fragmentation and forestry production. Because the study focuses on the impact of forest fragmentation and farmers' investment on forestry production, number of forest block is independent variable and unit forestry production is dependent variable. The Production function means that under certain technological level, a fixed amount of investment relies on the production possibilities. Investment includes labor, capital and land. In this study, independent variables are determined and explained as follow:

(1) Labor investment (LDTR): standard working hours (day);

(2) Other investment (WZTR): including seeds, chemicals, nutrients and miscellaneous inputs;

(3) Land area (LDMJ): area of operated forestland;

(4) Level of forest fragmentation (LDXSCD): number of forest block per household.

2.5.2 Model construction

The Cobb-Douglas production function can be expressed as

$$Y = \alpha_0 x_1^{\beta_1} x_2^{\beta_2}, \quad (6)$$

where Y is production and X_i stands for i^{th} input.

The number of forest block operated expresses change of forest fragmentation and thus it can not be used as one input variable. Based on the theories of developing economics and past experience, scaling operation is firstly impacted by the forest fragmentation. Because β_i (i = 1 ,2 … k) is elasticity, we construct a model that links this to that forest fragmentation:

$$\beta_i = \alpha_i + \gamma_i^{LnP} \ , i = 1,2 \ldots k. \qquad (7)$$

P in equation (7) stands for the number of forest block and plugs into the Cobb-Douglas production function, we can get:

$$Y = \alpha_0 \, x_1^{(\alpha_1 + \gamma_i \times LnP)} \times \times x_2^{(\alpha_2 + \gamma_2 \times LnP)} \times x_k^{(\alpha_k + \gamma_k \times LnP)} \ . \qquad (8)$$

Put natural log both sides, we get model II and it is expressed as

$$\begin{aligned} LnY &= Ln\alpha_0 + (\alpha_1 + \gamma_1 LnP)LnX_1 + \\ &+ (\alpha_2 + \gamma_2 LnP)LnX_2 \\ &+ \cdots\cdots + (\alpha_k + \gamma_k LnP)LnX_k \\ &= Ln\alpha_0 + \sum \alpha_1 LnX_i + \sum \gamma_1 LnPLnX_i \end{aligned} \ . \qquad (9)$$

From equation (8), the scale elasticity V can be expressed as

$$V = \sum \beta_1 = \sum (\partial_1 + \gamma_i LnP) = \sum \alpha_{i+} LnP \sum \gamma_i =$$
$$= \gamma_0 LnP + \sum \alpha_i, \ \text{ where } \gamma_0 = \sum \gamma_i \, .$$

Model II is the extension of Cobb-Douglas production function and can be used to examine the impacts of forest fragmentation on scale economy. Variable P should be a positive integer. When forest fragmentation does not exist (P=1), it returns to standard Cobb-Douglas function.

Two potential problems exist in model II. The first problem is the new variable $LnPLnX_i$ or $PLnX_i$ may have multi-linearity and the second problem is the property in standard Cobb-Douglas production function cannot be retained. One way to solve this problem is to add one constraint that all γ_i are equal.

That is

$$\gamma_1 = \gamma_2 = \ldots = \gamma_k = \gamma \ . \qquad (10)$$

Therefore, we can get model III:

$$LnY = Ln\alpha_0 + \sum \alpha_i Ln\chi_i + \kappa\gamma(LnP \sum Ln\chi_i). \qquad (11)$$

The coefficient corresponding to scale economy is defined by $\sum \alpha_i + k\gamma LnP$ (under linear scale function, it is defined by $\sum \alpha_i + k\gamma P$). Therefore, if we find that $\sum \gamma_1$ or γ is less than 0, then forest fragmentation has negative impacts on scale economy and forestry production. The selection of scale function (linear or semi-log) depends on the value of R^2 and likelihood.

2.4.3 Result of model estimation

(1) Variable description

Survey data used in this empirical study collected from farmers among nine provinces in 2009. Forestry commodities include wood, bamboo, bamboo shoots, economic forest product 1, economic forest product 2, economic forest product 3, fuel wood and non-wood forest products. Output is calculated on a household basis and plant area is in hectares, physical investment is in dollars and labor is determined by working days. From the data obtained, the major products are wood and bamboo while others are in a relatively small number.

(2) Model fitness and selection

Before we estimate the models, we analyze the likelihood function and R^2 (fitness of the samples and regression line) in order to select the models. The selection result shows that bamboo shoots, economic forest product 2, economic forest product 3 should be linear in the model. When using R^2, likelihood value is higher in economic forest products and others are low (see *Table 9*).

(3) Model selection

From *Table 10* we can see that when wood is output, only LDXSCD has negative impacts within four independent variables, which is the same as our expectation. Other variables such as labor, land and capital have positive impacts on forestry outputs. T value of corresponding γ of physical investment is greater than 2, which indicates that the positive impact of physical investment is significant. However, the γ of forest fragmentation shows the negative impact of forest fragmentation is significant. The estimated result of bamboo is different from our expectation where the LDXSCD does not have negative impacts on forestry production while the LDMJ has the negative impacts and labor has positive impacts. From the coefficient of forest area, we see that the negative impact of bamboo area is significant.

Table 9. The results of model selection

Crop	Scale function	Goodness of fit R^2	Final selection model
Wood	Linear model	0.135342	
	Logarithmic model	0.267122	Logarithmic model
Bamboo	Linear model	0.025012	
	Logarithmic model	0.036994	Logarithmic model
Bamboo shoots	Linear model	0.676175	
	Logarithmic model	0.269619	Linear model
Economic forest product 1	Linear model	0.066245	
	Logarithmic model	0.095661	Logarithmic model
Economic forest product 2	Linear model	0.875314	
	Logarithmic model	Not applicable	Linear model
Economic forest product 3	Linear model	0.735718	
	Logarithmic model	0.667665	Linear model
Fuel wood	Linear model		
	Logarithmic model	0.057076	Logarithmic model
Non-wood forest products	Linear model	Not applicable	abandoned
	Logarithmic model	Not applicable	

Table 10. The main indicators of the wood, bamboo model estimating

Explanatory variables	Crop					
	Wood			Bamboo		
	Coefficient γ	*t* value	*p* value	Coefficient γ	*t* value	*p* value
LDTR	0.209085	1.624927	0.1069	0.247387	1.830346	0.0686
WZTR	0.316939	4.187608	0.0001	0.002072	0.022804	0.9818
LDMJ	0.219486	1.952609	0.0533	-0.19599	-2.17862	0.0305
LDXSCD	0.33482	-2.9077	0.0489	0.032924	0.876812	0.3816

3. Conclusion and discussion

The collective forest rights reform is the basis of China's forest fragmentation. Because of natural geographic and resource differences, effects of forest fragmentation become even stronger. The latest forest reform also increases the level of fragmentation. Survey data shows that the total block number has increased by 16.12% with the highest increase in Guangxi and Liaoning and smallest increase in Hunan.

The result also shows that even forest rights have been determined; the number of forest block does not increase per household. This tells that the latest forest rights reform only has limited impact on forest fragmentation. Compared the data, we find that mountainous area has more significant impacts on forest fragmentation than the plain area, but the impacts are limited by the spatial constraint and time lags. Statistics of number and size of block and average area of forest show that China's forest fragmentation is not very high. Therefore, the living standard and household forest fragmentation does not increase in the same speed. Rather, dividing forest to household increases the size of forests owned by farmers, which push the scale forest operation. In general, scale effects mean lower production cost or higher production when operating expands. For this reason, we should not encourage land monopoly.

The quantitative analysis indicates that under certain S index intervals, the higher then level of forest fragmentation, the more difficult for farmers to invest. But when the level of forest fragmentation is lower than 0.22 or higher than 0.51, it would help investment. The same logic applies for the investment-income ratio. This says that the level of forest fragmentation and investment do not have negative linear correlation and the development of scale operation and investment do not have positive linear correlation, which is the same as the field survey. The main reasons for low investment include lack of capital and labor low profits from forestry. Lacking of labor is due to the large-scale operation and high salaries. This indicates that under current operating condition, appropriate labor supply and external capital support must be an important policy suggestions to keep scale forest operation.

Fragmentized forest operation has negative impacts to forest wood production but no significant impact on bamboo. For bamboo, investment level is the most important factor to its output and when the capital is not sufficient, the larger the size of bamboo forest, the unit output is lower due to decrease on average investment. Therefore, labor, physical and ground investment have positive impacts on wood and bamboo products where the physical investment has the largest effect. This also means that after the land is divided to households, physical investment is the key factor to affect the commodity output and should be considered by the related policies to increase the incentives of farmers.

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