Location and economic resilience in rubber farming communities in southwest China

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Abstract

Purpose – In rural areas, geographic location is key to market access and labor mobility of farm households. This paper aims to investigate the opportunities and constraints of smallholder rubber farmers in southwest China to adjust to the changes in economic and institutional conditions, namely the declining rubber prices, emerging land rental markets and growing off-farm job opportunities.

Design/methodology/approach – The empirical basis is a dataset of some 600 rubber farmers in Xishuangbanna Dai Autonomous Prefecture, Yunnan Province, collected in March 2015. The study uses instrumental variable and recursive bivariate probit models to account for possible endogeneity and selection bias.

Findings – With rubber prices in decline, the elevation of rubber plantations is an essential factor for the costs of access to the local factor markets and influences farm households' possibilities to adopt coping strategies. Notably, we find a *U*-shape type of relationship between the location and renting-out land due to the decline in rubber profitability. Rubber producers in low elevations are better bestowed with access to local markets. Households in high elevations, where rubber planting came in later, can shift to new crops like tea. However, the economic resilience of farmers in middle elevations is low due to their higher adjustment costs.

Originality/value – The paper provides a constructive basis for designing more location-specific development policies and can help avoid the past often ineffective blanket measures. Its implications have significant relevance for areas with similar conditions, for example, the remote, ethnic minority–dominated and mountainous rural areas in China.

Keywords Rubber, Elevation, Land rental, Off-farm employment, Southwest China

Paper type Research paper

1. Introduction

Over the last four decades, China has witnessed unprecedented economic growth, which has significantly reduced poverty in urban and rural areas. Between 1978 and 2018, China's gross domestic product (GDP) grew at an average annual rate of 9.4% (National Bureau of Statistics

JEL Classification — J61, Q12, Q15

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China, 2019). While most of the gains in income and wealth have occurred in urban areas, rural regions have benefited from transferring surplus labor to urban industrial centers. In rural China, structural change is underway, for example, through the development of land rental markets and off-farm employment opportunities (Huang *et al.*, 2012; Deininger *et al.*, 2014). Nevertheless, rural China's development has been lagging behind the cities, which has widened the urban–rural divide (Bao *et al.*, 2002; Xie and Zhou, 2014; Li and Wan, 2015). Despite reducing chronic poverty, for rural households, especially in the remote, mountainous, border and minority areas, vulnerability to poverty is still high (Liu *et al.*, 2017).

Xishuangbanna Dai Autonomous Prefecture (XSBN) in the southwest of Yunnan province is a good example. XSBN is characterized by high ethnic diversity, with the Dai ethnicity forming the majority group. It is also one of China's ecologically most valuable areas with tropical rainforest rich in flora and fauna. For agriculture, however, the natural conditions are challenging. Traditionally, subsistence farming with food crops like rice and maize have been the dominant agricultural system. Hence, in the past, the poverty rate has been high.

When China started implementing its economic reforms during the 1970s, the government introduced natural rubber in XSBN as a poverty reduction strategy. Initially, the concept was large-scale state farms. These, however, were later transferred to mostly local smallholder farmers. Mainly fueled by rising commodity prices, rubber plantations rapidly expanded (Xu *et al.*, 2014), traditional agriculture has been gradually giving way to the flourishing smallholder production of rubber.

The transition of land-use systems from diverse cropping systems and agroforestry to rubber monoculture has been significant (Xu, 2006). By 2014, the total area of rubber plantations in XSBN reached 300,000 ha, almost one-third of China's rubber plantations (Bureau of Statistics of XSBN, 2015). Historically, rubber expansion started in lowland areas below 600 m above sea level (MASL). Land areas located in elevations up to 800 MASL are ideal for rubber growing. However, rubber has moved beyond that level and has been growing in high elevations, despite lower productivity, against rubber experts (XSBN Biological Industry Office, 2013).

By 2011, the rubber price started to decline (see Figure A1 in Appendix). The resulting drop in incomes forced farmers to adjust their livelihood strategies. The main options hereby are renting out land, often to outside investors, and shifting to off-farm employment. Clearly, location plays an essential role in buffering the rubber price shock. Farmers living in the places where they can gain access to local factor markets and more flexible labor mobility are more resilient to this shock that has persisted over eight years. However, how the location interacts in affecting this process is not well understood in such remote, mountainous and minority rural areas of China.

In this paper, we undertake an analysis of farmers' decisions regarding land rental and off-farm works as a coping strategy in rural XSBN in light of the decline in rubber prices. We mainly identify the role of elevation as an essential location factor, in determining farmers' level of economic resilience. To facilitate our analysis, we follow up the study of Min *et al.* (2017a) and distinguish three elevation zones, namely lowland area (below 600 MASL), middle-elevation area (600–800 MASL) and highland areas (above 800 MASL) [1]. As in Min *et al.* (2017a), farmers located in different elevation zones in XSBN exhibit considerable heterogeneity in their livelihoods, land use and rubber production. We hypothesize that location is vital as it influences the cost of access to the local factor markets and labor mobility and the history of natural rubber introduction and their adoption by smallholder farmers.

We outline a conceptual model to capture the smallholder rubber farmers' process to cope with rubber price shocks. The model allows distinguishing patterns of land rental and off-farm work decisions and activities at different elevation levels. Location matters for access to land rental and off-farm labor markets. Our conceptual model points to a nuanced and bidirectional connection between land rental (as rent-out in our case of study) and off-farm work participation.

This study's empirical basis is a comprehensive cross-sectional database of smallholder rubber farmers from XSBN, collected in March 2015. To test the hypotheses, we use instrumental variable probit and recursive bivariate probit models, which allow identifying the role of elevation in determining land rental and then estimating the impact of the land rental decision on off-farm employment.

The paper results show that the degree of economic resilience of smallholder farmers differs significantly across elevation levels. Farmers in lowland areas tend to shift out of rubber and engage in off-farm employment, while those in the highland tend to diversify into other crop cultivations, mainly tea. Farmers located in the middle-elevation areas transform less due to limited possibilities to enter the local factor markets and less-favored geographic labor mobility. Besides, the direct connection between elevation and off-farm work is not significant.

The implications of this study are essential for the rubber industry in XSBN. The study is also relevant for areas with similar conditions, for example, the remote, ethnic minority–dominated and mountainous rural areas in China. A distinct goal of China's government poverty-reduction policy declared in 2015 is to lift people out of chronic poverty in the less-favored minority regions. Our study demonstrates the disparity and constraints that arise from the locations of rubber farmers.

The rest of the paper is organized as follows. Section 2 develops the conceptual framework that underlies the empirical work. Section 3 specifies the empirical estimation approaches. Section 4 introduces the data collection in the field survey and the results of descriptive statistics. Model results are presented in Section 5, and in Section 6 the paper concludes.

2. Conceptual framework

This section introduces a conceptual model of the patterns and interrelations of farmers' decisions of participating in land rental and off-farm labor markets at different elevations in the mountainous region of XSBN.

The model was initially developed by Deininger and Jin (2006). Their model differentiates land tenure security and transferability and explores impacts on land-related investments and productivity. We extend this model and add location as a proxy for the cost of access to land rental and off-farm labor markets. In our model, location refers to the three elevation categories of rubber plantations described in the previous section. To capture rural land rental markets' conditions in the model, we included tenure security as an exogenous variable (Wang *et al.*, 2018). Hence in our framework (see Figure 1), we outline triangular correlations: (1) *elevation and land rental decisions*, (2) *elevation and off-farm work participation* and (3) *land rental decision and off-farm work participation.*

Formally, a household endowed with identical labor $\overline{L}_{t\ \mathrm{Unit}}$ s, and capital stock K_t includes landholding and its productivity. The utility is defined as consumption in any period, C_t by a standard utility function of the form $U(C_1, C_2) = \ln(C_1) + \delta \ln(C_2)$ where δ is the discount

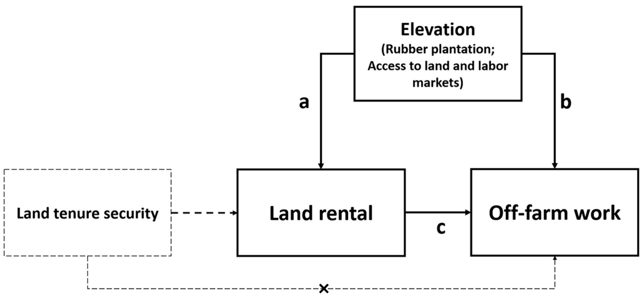


Figure 1.
Conceptual framework

factor. Household income can be derived either from agricultural activities according to a production function $y_t = f(K_t,\ l_t^a)$, where l_t^a denotes the amount of labor time engaged in the farm production and time spending l_t^o in off-farm employment at a given exogenous wage rate w_t. In the initial period, households can adjust an amount of time Δl_1^o and increase the time spent in off-farm employment. But as a consequence [2], the capital stock (landholding and its productivity) in the second period would be diminished to $K_2 = K_1 - g(\Delta l_1^o)$. We assume that $g(\cdot)$ is a concave function, i.e. $g' > 0$ and $g'' < 0$.

To illustrate the covariate price shock, we assume a nonzero probability θ that household rents out land at a rental rate r, which is a concave function of the value of the land-attached capital stock in the second period, i.e. $r = r(K_2)$, as a response to the falling rubber prices. To capture the cost of access to land rental and labor markets, we define a proportional parameter $T \in [0,\ 1]$ as a concave function of the location-related elevation e. That is, $T = T(e)$ with $T' > 0$ and $T'' < 0$. A smaller value of T indicates lower access costs to land rental markets and other in-kind costs. In line with Deininger and Jin (2006), access costs to land markets can be considered as a tax on land rents. As the landowner, the household obtains the lease of land, $(1 - T(e))r$. After renting out θ share of land, the household can still invest the rest capital, $(1 - \theta)K_2$, in agricultural production in the second period.

In addition, the household risks losing land rights, which is conditional to the amount of labor used on land by requiring that it kept in production at an accepted standard of use; otherwise, the land is in a certain probability to be reallocated to more productive users by the local government. Thus, we define $\rho \in [0,\ 1]$ to be the land tenure insecurity implying the probability of land loss in the second period. Therefore, modified from Deininger and Jin (2006), the household's utility maximization problem can be described as:

$$\begin{aligned} &\max U(C_1,\, C_2) = \ln(C_1) + \delta \ln(C_2) \\ &\text{s.t. } \delta\left[f\left(K_1,\, l_1^a\right) + l_1^o w_1 - C_1\right] + \left[\rho f\left((1-\theta)K_2,\, l_2^a\right) + (1 - T(e))r(\theta K_2) + l_2^o w_2 - C_2\right] = 0, \\ &l_1^a + l_1^o + \Delta l_1^o \le \overline{L}_1, \\ &l_2^a + l_2^o \le \overline{L}_2. \end{aligned} \tag{2.1}$$

With the separability between consumption and production, the maximization problem simplifies to:

$$\begin{aligned} &\max_{l_1^a, l_1^o, \Delta l_1^o, l_2^a, l_2^o} \delta\left[f\left(K_1,\, l_1^a\right) + l_1^o w_1\right] + \left[\rho f\left((1-\theta)K_2,\, l_2^a\right) + (1 - T(e))r(\theta K_2) + l_2^o w_2\right] \\ &\quad \text{s.t. } l_1^a + l_1^o + \Delta l_1^o \le \overline{L}_1, \\ &\quad l_2^a + l_2^o \le \overline{L}_2. \end{aligned} \tag{2.2}$$

Solving this maximization problem, we have the following first order conditions (hereafter, FOCs) after the labor binding conditions are substituted into the objective function,

$$f'\left(K_1,\, l_1^a\right) - w_1 = 0, \tag{2.3}$$

$$f'\left(K_1 - g\left(\Delta l_1^o\right),\, l_2^a\right) - w_2 = 0, \tag{2.4}$$

$$\begin{aligned} \text{and } \delta\left[f'\left(K_1,\, l_1^a\right)\right] + \Big[\rho f'\left((1-\theta)\left(K_1 - g\left(\Delta l_1^o\right)\right),\, l_2^a\right)(1-\theta)g'\left(\Delta l_1^o\right) \\ + (1 - T(e))r'\left(\theta\left(K_1 - g\left(\Delta l_1^o\right)\right)\right)\theta g'\left(\Delta l_1^o\right)\Big] = 0. \end{aligned} \tag{2.5}$$

Substituting Eqs (2.3) and (2.4) in Eqn (2.5) yields:

$$\delta w_1 + w_2 g' (1-\theta) + (1-T(e)) g' r' \theta = 0. \tag{2.6}$$

Next, in combination with our conceptual framework, we establish three hypotheses as follows:

2.1 Relating elevation to land rental decision

First, we outline the interrelationship between the elevation and the household's decision of land rental. The total differentiation of Eqn (2.6) for θ and $T(e)$ provides:

$$\frac{\partial\theta}{\partial T(e)} = \frac{-r'\theta}{(1-T(e))[r' + (K_1 - g)r''\theta] - w_2}. \tag{2.7}$$

In Eqn (2.7), we find the effect of market access cost (T) as a function of elevation (e) on the household's land rental decision (θ) would be influenced by the capital K_1 and its loss g that occurred in the initial period. Therefore, in the second period, the household's decision-making process would be affected by the investments (K_1) or labor activities $(g(\Delta l_1^o))$ in the initial period. We further interpret the sign of $\frac{\partial\theta}{\partial e}$ under different conditions.

If $(1-T(e))[r' + (K_1 - g)r''\theta] - w_2 > 0$, can be written up as:

$$T(e) < 1 - \frac{w_2}{r' + (K_1 - g)r''\theta} \tag{2.8}$$

which yields, $\frac{\partial\theta}{\partial T(e)} < 0$.

If $(1-T(e))[r' + (K_1 - g)r''\theta] - w_2 < 0$, can be given as:

$$T(e) > 1 - \frac{w_2}{r' + (K_1 - g)r''\theta} \tag{2.9}$$

which yields, $\frac{\partial\theta}{\partial T(e)} > 0$.

The term on the right-hand side of the inequality Eqs (2.8) and (2.9) can impose an interval solution of $T(e)$ in which the household presents the lowest likelihood of renting-out land. Given $\theta \in [0,1]$, $r' < 0$ and $r'' < 0$, we will have an inequality interval:

$$1 - \frac{w_2}{r' + (K_1 - g)\ r''} \leq T(e) = 1 - \frac{w_2}{r' + (K_1 - g)r''\theta} \leq 1 - \frac{w_2}{r'}. \tag{2.10}$$

It implies, for any $T(e) \in \left[1 - \frac{w_2}{r' + (K_1 - g)r''}, 1 - \frac{w_2}{r'}\right]$, the term $\frac{\partial\theta}{\partial T(e)}$ will take its lowest values, i.e., the lowest probability for the household to rent out its land. Regarding the access cost (T) as a concave function of elevation (e), we thus rewrite the connection between e and land rental θ as:

$$e \in \left[T^{-1}\left(1 - \frac{w_2}{r' + (K_1 - g)\ r''}\right),\ T^{-1}\left(1 - \frac{w_2}{r'}\right)\right]. \tag{2.11}$$

This generates the first hypothesis as follows (see route a in Figure 1):

H1. The relationship between elevation and farmers' decisions of renting out land follows a U-shape relationship. Thus farmers in areas of lower- (i.e. smaller e) or higher-elevation (i.e. larger e) are more likely to rent out their land, while those in middle elevations are not.

2.2 Relating elevation to off-farm work participation

Next, we outline the role of elevation in the determination of off-farm work participation. The total differentiation of Eqn (2.6) for Δl_1^o and T provides:

$$\frac{\partial \Delta l_1^o}{\partial T(e)} = \frac{g' \ r' \theta}{w_2 g''(1-\theta) + (1-T)(\ r''\theta + g'' \ r')\theta} < 0 \,(\text{given}\, g' > 0,\, g'' < 0,\, r' > 0 \,\text{and}\, r'' < 0) \tag{2.12}$$

As explained above, the access cost (T) is a function of elevation (e) with $T'(e) > 0$. We then have $\frac{\partial \Delta l_1^o}{\partial e} < 0$. Therefore, we can have the second hypothesis (see route b in Figure 1).

H2. Farmers in the lower elevation (i.e. smaller e) gain a higher participation rate in the local labor market (i.e. higher Δl_1^o).

2.3 Relating land rental to off-farm work decision

Finally, we outline the bidirectional relationship between the household's land rental decisions and off-farm work participation. The total differentiation of Eqn (2.6) for Δl_1^o and θ provides,

$$\frac{\partial \Delta l_1^o}{\partial \theta} = \frac{g'\{w_2 - (1-T)[-r' + (K_1 - g)r''\theta]\}}{w_2 g''(1-\theta) + (1-T)\theta[g''r' - (g')^2 r''\theta]} = h(T(e), \theta). \tag{2.13}$$

According to the form of Eqn (2.13), we find an intertwined relationship between the decisions of land rental and off-farm employment, indicating that $\partial \Delta l_1^o / \partial \theta$ is a function of both access cost $T(e)$ and the proportion of land rented out θ. This suggests the existence of endogeneity, which potentially stems from the unobserved household characteristics (e.g. skills and abilities of farmers [3]) that are correlated with both the off-farm work decision and the land rental decision. The estimations may produce "spurious" correlations and biased estimates of the effects of the land rental (θ) as a coping strategy under the covariate price shock on the off-farm participation decision (Δl_1^o). For example, conditional on the same characteristics and endowments, farmer A enjoying better skills can find a higher-payment job than farmer B with lower skills. Therefore farmer A may be more likely to stay in the labor market and rent the land out. Land tenure security can be used as an instrumental variable to establish the causal impact of the land rental decision on the off-farm employment decision. It is based upon the logic that tenure security will not influence a household's off-farm employment decision directly but indirectly through the channel of land rental decision (see Route c in Figure 1).

H3. There is a bidirectional relationship between the decisions of renting out the land and taking up off-farm work. Accordingly, engaging in off-farm jobs facilitates renting out land, while access to land rental markets releases the laborers and increases households' likelihood of off-farm work participation.

These three hypotheses will be tested using the empirical strategies specified in the next section.

3. Estimation specification

Following the conceptual model, the empirical strategy is specified. We use an instrumental variable (IV) [4]. Moreover, recursive bivariate probit (RBP) models to assess the impact of the land rental decision on off-farm employment participation. The model accommodates potential endogeneity and self-selection problem. As instruments, we employ two variables: (1) "*whether the household land was entitled to both farmland and forestland certificates*" referring to the objective tenure security and (2) "*whether the land certificates were believed to be extended when expired in the future*" relating to the respondent's self-assessed tenure security.

The relationship between land rental decision and off-farm work participation is formalized in the following model:

$$O_i^* = f(R,\ E,\ X;\ \alpha) + \varepsilon_i \quad O_i = I\left[O_i^* > 0\right] \tag{3.1}$$

where O_i^* is a latent variable capturing the decision of off-farm work participation; R is a binary indicator variable which equals 1 if the household i chooses to rent out land and 0 otherwise chosen; E is a set of dummy variables associated with the groups of elevation (i.e. low-, middle- and high-elevations); X denotes the vector of household characteristics involving the characteristics of rubber farming, household members and local village communities; α is a vector of parameters to be estimated and ε_i is the error term.

Next, we introduce an equation to model land rental decisions. We estimate the relationship between elevation and land rental market participation as follows:

$$R_i^* = d(E,\ Z;\ \beta) + u_i \quad R_i = I\left[R_i^* > 0\right] \tag{3.2}$$

where R_i denotes the land rental decision; E is the elevation variable; Z includes a vector of factors that influence farmers' decision of renting out the land; β is a vector of parameters to be estimated and u_i is the error term.

Suppose the same unobservable factors (e.g. farmers' capability and motivation to enter the land and labor markets) influence both the error term (ε_i) in the off-farm work equation and the one (u_i) in the land rental equation. In that case, it may produce spurious correlations and give biased estimates. Farm households partially involved in the off-farm sector can rent the land out to save the forgone labor inputs supplied to the off-farm employment. The potential endogeneity may occur in two ways: the endogenous covariance and the self-selection bias. Rigorous estimates of the effect of farmers' land rental on off-farm work decisions should account for both categories of endogeneity.

To estimate both the marginal effects and average treatment effects of land rental on off-farm work participation, we use the RBP maximum likelihood estimation as applied by several empirical studies (e.g. Castello, 2012; Lanfranchi and Pekovic, 2014; Ma *et al.*, 2017). The results of the validity test of IVs and goodness-of-fit to justify the use of the IV and RBP models are shown in the Appendix.

Using the RBP model, we further estimate the average treatment effects on the treated (ATT), using the method developed by Chiburis *et al.* (2012) to capture the causality of the land rental decision on the likelihood of participating in the local labor market. The ATT is computed using the following expression:

$$\text{ATT} = \frac{1}{N}\sum\nolimits_{i=1}^{N}\{\Pr(O_i = 1|R_i = 1) - \Pr(O_i = 0|R_i = 1)\}. \tag{3.3}$$

4. Data and descriptive statistics

This section shows the initial descriptive analysis based upon a comprehensive dataset collected in rural XSBN. We start this section by introducing the sampling procedure and data collection, as applied in this study. Next, using this dataset, we will introduce the rubber expansion at different elevations in the mountains of XSBN. Finally, we will present farmers' coping processes against price risks with information on their actual participation in land rental and off-farm employment in the context of the latest land-related institutional reforms in XSBN.

4.1 Sampling and data collection

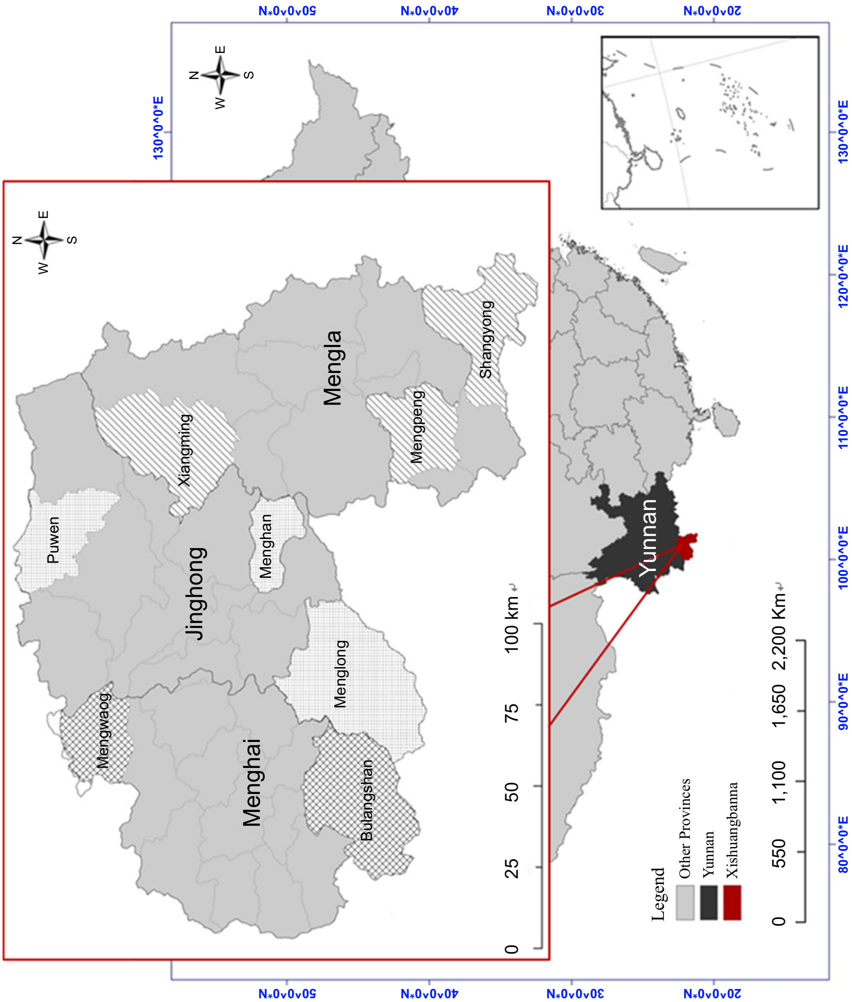
Xishuangbanna Dai Autonomous Prefecture (XSBN) is located in the south of Yunnan Province in China. Geographically it belongs to the Greater Mekong subregion, bordering Laos and Myanmar in the South. The prefecture governs one city and two counties, namely, Jinghong, Menghai and Mengla, including 32 townships in total. The entire landscape of XSBN covers more than 19,000 km^2 , wherein 95% is a mountainous region ranging from 475 to 2430 MASL. XSBN is also culturally diverse. Until 2018, the total registered population of XSBN has risen to 1.01 m, of whom 78.5% are different ethnic groups. The majority of the population in XSBN are Dai with over 30%, followed by Hani, Bulang, Jinuo, Miao and Yao. Rich ethnic culture leads to multiple patterns of livelihoods and agricultural practices (Min *et al.*, 2017a).

In the 1950s, the government introduced rubber planting to XSBN by establishing state rubber farms (Fox and Castella, 2013). After China's agricultural reforms in the 1980s, rubber spread rapidly to smallholders indigenous to the area (Xu, 2006). Facilitated by flexible land policies, sufficient farmland and labor force as well as continuously rising commodity prices, the smallholder rubber plantations soon dominated XSBN and its rural economy. The growth in rubber-dominant agriculture contributed to significant poverty reduction and improvements in rural households (Min *et al.*, 2017a).

After 2011, the economic conditions have changed unexpectedly for many smallholder rubber farmers. On the one hand, the rubber prices reached a peak and followed by a longstanding decline, which led to tremendous losses in household incomes. The boom of the rubber economy then came to an end. On the other hand, the nonfarm economy has been emerging in China. Motivated by the rising wage rates, the agricultural labor force's share in the nonfarm employment continues to increase (Wang *et al.*, 2016). XSBN is not an exception, though it is far away from China's economic centers and hotspots.

This study has a unique dataset from a household survey of some 612 smallholder rubber farmers [5]. In XSBN, the survey was jointly conducted by Leibniz University Hannover (LUH) and China Center for Agricultural Policy (CCAP) in March 2015, capturing all characteristics and economic activities. We applied a stratified random sampling approach to obtain a representative sample of rubber farmers. The sample was drawn in a three-stage process, including three counties, eight townships and 42 villages. The regional location of samplings is depicted in Figure 2.

For sampling, we consider the size of rubber area per capita and the distribution of rubber plantations in each county, being well able to picture the smallholder rubber farming in XSBN. The sample households in XSBN are located between 540 and 1500 MASL. The survey instruments included household and village questionnaires. The household dataset consists of all family members' socioeconomic information, including all income-generating activities, such as crop and livestock production, as well as off-farm and nonfarm activities. The household questionnaire also included a detailed rubber production module to capture the labor input, material use and outputs. The village questionnaire, which was administered with the head, included demographic conditions, infrastructure and institutions in the local village communities. An interview with one household took around two hours. After the interview, farmers received 50 RMB and some small gifts (e.g. daily necessities) for their time costs during the interview. For the enumerators, following a rigorous training procedure for one week, we selected and trained some 30 college students from XSBN who knew well the local dialect and culture. The survey provides comprehensive information on land rental and off-farm behaviors, household members' characteristics, rubber farming and other economic activities. Our samples depict the geographical features in XSBN.



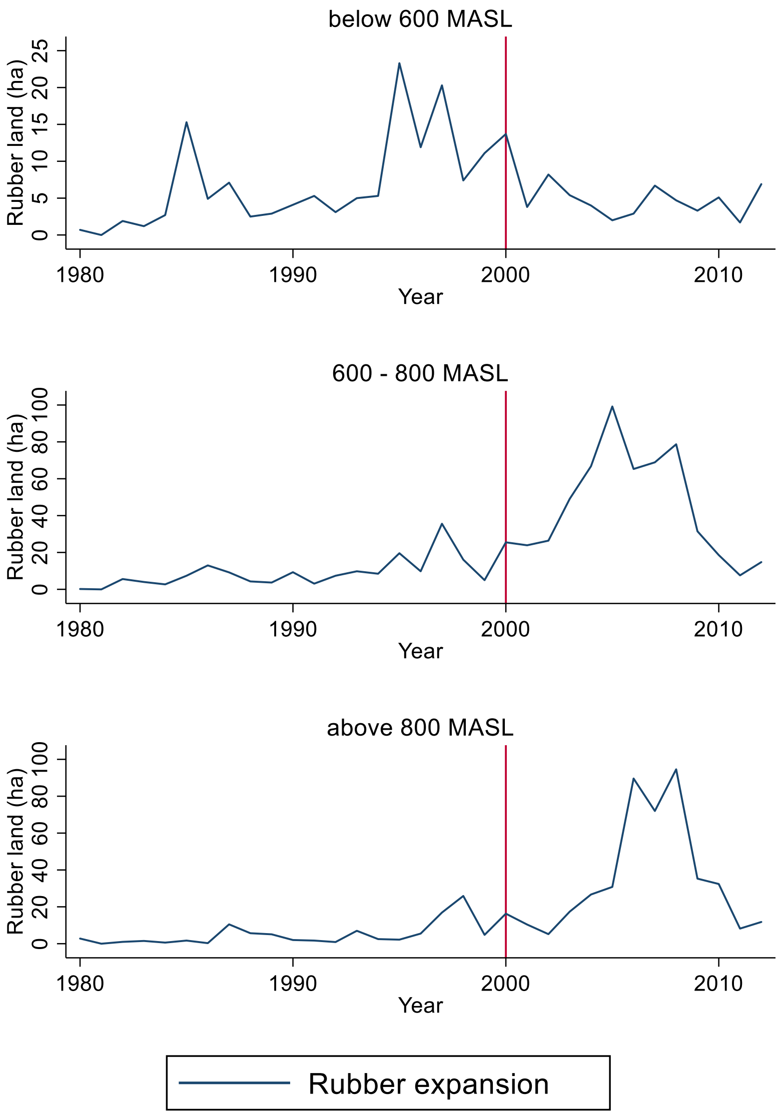
Source: Adapted from Min et al. (2017a); Authors' survey

Figure 2.
Location of XSBN in southwest China

In summary, the dataset gives a comprehensive perspective on the coping behaviors in land use and labor supply in the periods of rubber price decline in XSBN. The detailed definitions and summary statistics of variables that involved criteria by elevation groups can be found in Table A1 in the appendix.

4.2 Elevation and the expansion of rubber plantation

Over the decades, smallholder farmers' rubber plantations extended from the lower elevations to the highland areas in XSBN. In Figure 3, we depict the rubber expansions at



Source(s): Authors' survey

Figure 3.
Rubber expansion in XSBN

different elevation areas since the 1980s. Two waves of large-scale expansion below 600 m occurred before the 2000s. Due to limitations in the land, the continued expansion took place in higher elevations.

In Figure 4, we plot kernel density of rubber land plots by tree age and yield, respectively. We focus on the proportions of land plots in different growth phases of rubber trees. In XSBN, the rubber's economic life cycle duration is around 30 years on average, and it takes until about seven years before the harvesting of latex can occur. After that, the productivity of rubber trees increases until year 20 and then gradually declines. At the x-axis on the left side of Figure 4, we label the tree age at 7 and 20 years. We observe that most rubber land is in the harvesting phase for rubber plantations below 600 m, while many of those above 600 m are still in the nonharvesting phase. For the years to come, most rubber trees can be tapped and will enter the harvesting phase for farmers above 600 m, while those in the areas below 600 m are confronted with declining yields due to tree age. On the right side of Figure 4, there are substantial proportions of rubber trees that produce no yield in all elevation groups. This is because some rubber plots are still in the nonharvesting phases. In addition, rubber farmers temporally stop tapping due to rubber price decline or family labor shortages. On the other hand, rubber yields in lower elevations are higher than those in the highlands.

4.3 Land institution, land rental and off-farm work participations

This sub-section shows the extent of land rental and off-farm labor market participation of smallholder rubber farmers. We first analyze the land rental markets. It is worth mentioning that while the new land certification reforms in rural China were established in early 2008, the process of land titling program [6] in XSBN, the land certification was still ongoing by 2014. This application includes both farmland and forestland tenure certification. As described by Min *et al.* (2017b), there are several reasons why XSBN was falling behind the developments at the national level. On the one hand, land tenure verification costs are high, given the complicated geographic situation in this mountainous region. The conversion from public forest land is constrained by ambiguous ownership due to traditional land-use rights. As shown in Table 1, the average proportion of land issued with farmland tenure certificates is 21.8%, while the ratio of forestland tenure certificates is 67.6%. The latter is higher because the rubber is mostly tenured as forestland. Accordingly, tenure security, in general, is high.

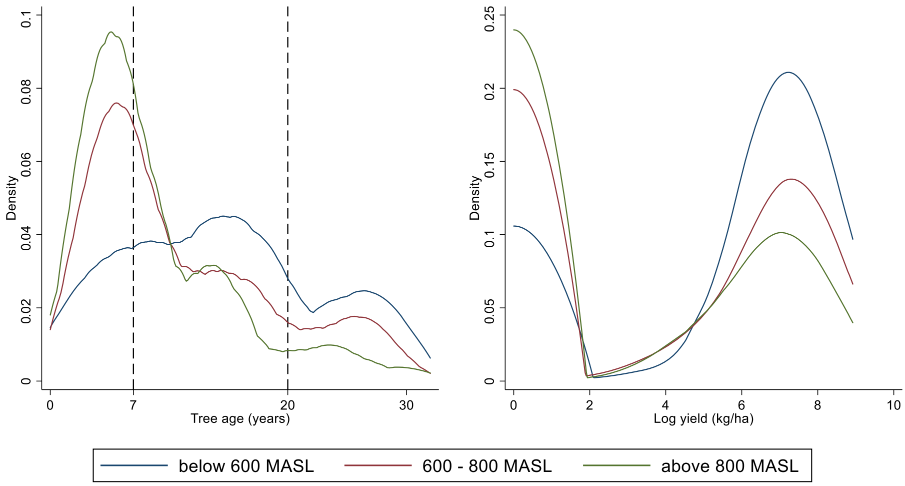


Figure 4.
Kernel densities of rubber tree age and yield using plot-level data

We do not find any significant difference in the percent of land under farmland and forestland certification (see Table 1).

In Table 2, we compare participation in land rental markets across the three elevation levels. Applying a t-test (using the middle-elevation level as the baseline), we find that the middle-elevation farmers who own the largest land endowments among the three groups have the lowest land rental participation rate, with 36% of the households renting out land. Low-elevation farmers have the highest land rental market participation, with 76% of the households and about 25% of their land. In the high-elevation, land rental market participation is lower than in the low elevation but above the middle elevation (see Table 2).

Next, at the household member level, we portray the job categories, contracting, the extent of agriculture engagement and the location of workplaces of the rubber farmers in the sample. As shown in Figure 5, we find the largest three categories of off-farm jobs are agriculture (30%), industry and production (24%) and service workers (18%). Most workers have informal contracts (i.e., verbal agreement) with their employers or do not have any warranty (see Figure 6). In Figure 7, we find only 38% of farmers do not engage in their agriculture, while the rest 62% are part-time workers who still have to engage in agriculture seasonally or frequently. Around 29% of workers' working places are within their villages, as is shown in Figure 8.

In the following, we explore the relationship between land rental and participation in the off-farm labor market. In Table 3, it can be seen that 47% of farm households rent out land to outside investors [7]. Local farmers are fully or partially engaged in off-farm employment. In

Table 1. Land proportion entitled to farmland and forestland tenure certificates

Categories	Farmland tenure certificate	Forestland tenure certificate
Overall	21.8	67.6
By elevation		
Low (below 600 MASL)	21.0	64.7
Middle (600–800 MASL)	23.4	69.1
High (above 800 MASL)	20.1	67.2

Note(s): t-test is conducted in the elevation groups regarded the group *middle elevation* as the baseline. * indicates significance at the p < 0.10 level, ** at the p < 0.05 level and ***p < 0.01 level
Source(s): Authors' calculation

Table 2. Farmers' participation in the land rental market, mainly as renting out land

Categories	Farm size (ha/person)	Land rental: The decision of renting out land (1 = yes; 0 = no)	Land rental: The proportion of land rented out (%)
Overall	0.91	0.49	13.5
By elevation			
Low (below 600 MASL)	0.73***	0.76***	26.1***
Middle (600–800 MASL)	1.03	0.36	8.9
High (above 800 MASL)	0.87**	0.49***	12.2**

Note(s): t-test conducted in the elevation groups regarded the group *middle-elevation* as the baseline. * indicates significance at the p < 0.10 level, ** at the p < 0.05 level and ***p < 0.01 level
Source(s): Authors' calculation

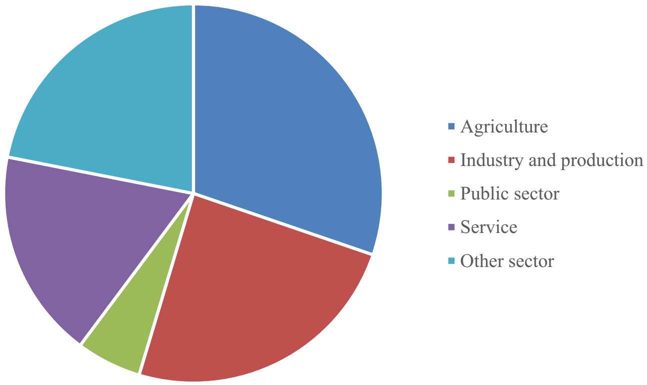


Figure 5.
Distribution of off-farm work categories

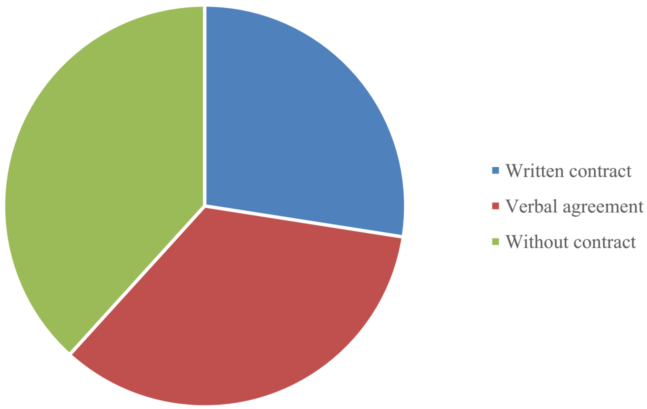


Figure 6.
Distribution of contracting

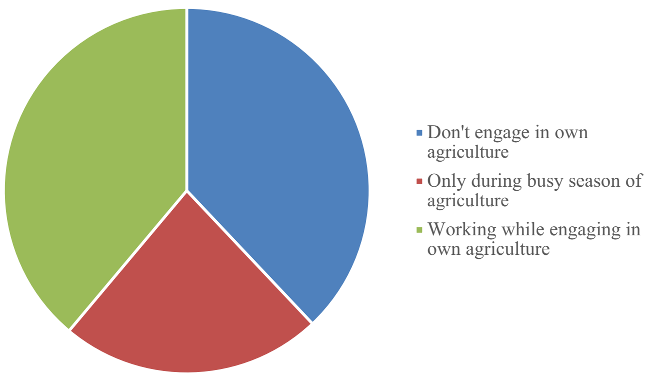


Figure 7.
Distribution of the extent of agriculture engagement

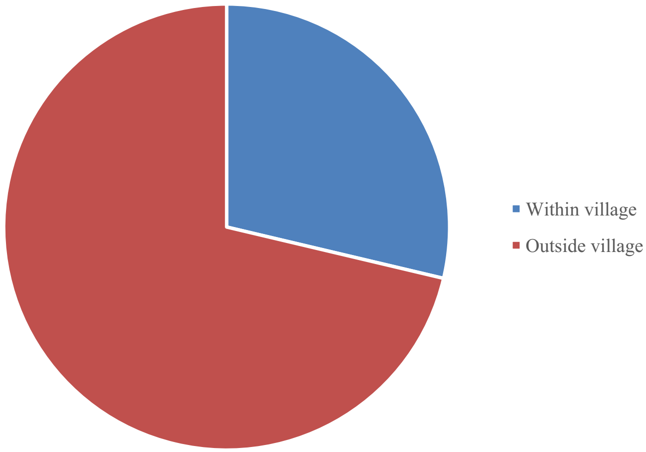


Figure 8.
Distribution of the working locations

Table 3.
Land rental and participation in the off-farm labor market

Categories	Participation in off-farm labor works (1 = yes; 0 = no)	The proportion of off-farm labor days in total labor inputs (%)
Rent-out	0.47***	13.38
Others	0.37	11.62

Note(s): The *t*-test is conducted. * indicates significance at the $p < 0.10$ level, ** at the $p < 0.05$ level, and ***$p < 0.01$ level
Source(s): Authors' calculation

comparison, the rate of participation in other households' labor market is significantly lower by 10%. Farmers who rent out land have a 1.76 % higher share of off-farm labor days than others. The results imply that farmers who lease out land are more likely to take up off-farm work.

5. Model results

In this section, we report the results of our three models. We start with the probit model results to identify the determinants of land rental decisions, which test the first hypothesis. Next, we report the model results that assess the impact of land rental participation on taking up off-farm work participation, referring to the second and third hypotheses.

5.1 Determinants of land rental decision

In Table 4, we show the marginal effects of the regression of the determination of land rental decisions using a probit model. To check the robustness of regression, we show different regression variants stepwise adding variable portfolios into the model. It can be seen that the coefficients of the elevation variables keep consistent in all the five models when more variables are added to the model (see column 1 to 5 in Table 4). This suggests that our estimation results are robust. The following discussion about the dependent variables' marginal effects is built upon the full-model result in column 5 of Table 4.

We can confirm our first hypothesis as the elevation coefficients depict a robust significant relationship with the land rental decision in all regressions. Specifically, farmers in the low-elevation areas show a 20.6% higher probability of renting-out land than farmers in

Table 4. Probit model for determination of land rental decision, marginal effects

Variables	Rent-out (1 = yes; 0 = no) (1)	(2)	(3)	(4)	(5)
Elevation groups					
Low (below 600 MASL)	0.275*** (0.052)	0.257*** (0.056)	0.224*** (0.057)	0.189*** (0.067)	0.206*** (0.067)
Middle (600–800 MASL)	−0.115*** (0.042)	−0.120*** (0.043)	−0.144*** (0.043)	−0.131*** (0.046)	−0.117** (0.046)
Labor		−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)
Material		−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)
Tree age		0.004 (0.004)	0.001 (0.004)	−0.003 (0.004)	−0.003 (0.004)
Dai			0.170*** (0.040)	0.159*** (0.041)	0.146*** (0.040)
Household size			0.044*** (0.014)	0.051*** (0.014)	0.048*** (0.014)
Age 16–40			−0.000 (0.001)	0.001 (0.001)	0.000 (0.001)
Age 41–65			0.001 (0.001)	0.001 (0.001)	0.001 (0.001)
Education			−0.005 (0.008)	−0.013 (0.009)	−0.011 (0.008)
Medium farm			0.093** (0.047)	0.145*** (0.051)	0.149*** (0.049)
Large farm			0.076 (0.054)	0.157*** (0.059)	0.159*** (0.058)
Assets middle 40%			−0.069* (0.041)	−0.072* (0.040)	−0.083** (0.040)
Assets top 10%			−0.046 (0.067)	−0.078 (0.066)	−0.098 (0.064)
Land Gini				−0.247 (0.186)	−0.184 (0.184)
Village off-farm rate				0.004*** (0.001)	0.003*** (0.001)
Land flatness				0.102** (0.043)	0.118*** (0.043)
Distance				−0.001 (0.000)	−0.001* (0.000)
Menghai				−0.142** (0.062)	−0.155** (0.063)
Jinghong				0.053 (0.049)	0.059 (0.048)
Land certification	0.148*** (0.042)	0.151*** (0.042)	0.115*** (0.042)		0.111*** (0.042)
Perception on land tenure	0.075 (0.048)	0.073 (0.048)	0.086* (0.047)		0.121** (0.047)
N	597	597	597	597	597
Wald χ^2	67.81***	69.97***	99.69***	102.60***	115.87***
Log pseudolikelihood	−379.06	−377.21	−358.84	−349.00	−342.17

Note(s): * indicates significance at the $p < 0.10$ level, ** at the $p < 0.05$ level, and ***$p < 0.01$ level. Robust standard errors in parentheses the high-elevation areas. There is an 11.7% lower probability of participating in the land rental market for farmers in middle-elevation regions than that of the base group in high elevations. This indicates a U-shape relationship between the elevation and land rental activities, consistent with the proposition derived from the conceptual model. The line of 800 MASL splits the economic potential of rubber farming in XSBN. Farmers above 800 MASL where rubber farming is less profitable, temporarily suspend management care of rubber [8]. Farmers below 600 MASL have lower costs to participate in the local land rental market, but also, like the early adopters of rubber cultivation, their investments have already paid off. These farmers are more flexible and can exit rubber production as their rubber trees have reached the age of declining productivity. On the other hand, farmers living in medium elevations do not have that same flexibility as they are more likely to experience sunk costs.

Ethnicity and household size can influence farmers' land rental decisions. Farmers who belong to the Dai ethnicity, the local majority in the population of XSBN, are more likely to rent out land indicating a 14.6% higher probability than other ethnic groups. For historical reasons, Dai farmers own most irrigable farmland in XSBN, which are more suitable for the cultivation of fruits and other cash crops and thus are more attractive for outside investors. Farmers with larger household sizes are more likely to rent out land as a means to smooth income. Land, capital and wealth are significant in influencing land rental decisions of rubber farmers. Larger land endowments result in a higher rate of participation in land rental markets. Poor farm households are more likely to rent out land, probably to cope with the income shock.

Households in villages with higher participation rates in off-farm employment are more likely to rent out land, the same as households in low elevations. Distance from the village community to the nearest town is negative and significantly correlated with land rental decisions. In the three counties, farmers in Menghai are less likely to rent out the land because of high access costs compared with the other two counties.

To deal with possible endogeneity when estimating the impact of the land rental decision on off-farm work participation, we include instrumental variables in the first-stage regression probit model. Results show that both objective and subjective tenure security contribute to a higher likelihood of land rental. Farmers who possess farmland and forestland certificates are more likely to rent out the land. This is reinforced by the significant coefficient "perception on land tenure," i.e. farmers' subjective judgment that the land tenure certificates will be extended.

5.2 Impact of land rental on off-farm work participations

The results of the probit, IV and RBP model are presented in Table 5. For the latter, the marginal effects are shown in column 4. Results of the first-stage regression for the IV and RBP models can be found in Table A2 of the appendix. Moreover, an exogenous test for the instrumental variables is shown in Table A3 of the appendix. More details in the validity of the estimation procedure are also available.

First of all, we use a probit model that excludes the land rental variable to test the direct impact channel of elevation on off-farm work participation. The results are displayed in column 1 of Table 5. We find a positive but insignificant correlation between these two variables, suggesting that farmers in various elevation zones have similar costs of access to the local labor market. Besides, the probit (including variable land rental), IV and RBP models support this finding (see columns 2 to 4). On the other hand, a direct effect of elevation on off-farm work participation cannot be confirmed. Hence we must reject the second hypothesis.

The models' results support the notion that access to the land rental market increases the likelihood that rubber farming households turn to off-farm employment participation. The land rental variable's coefficient is significant at the 5% level after controlling for possible endogeneity in the IV and RBP model (see columns 3 and 4), whereas the coefficient is not

Table 5. Model estimates for the decisions of land rental and participation in the off-farm labor market

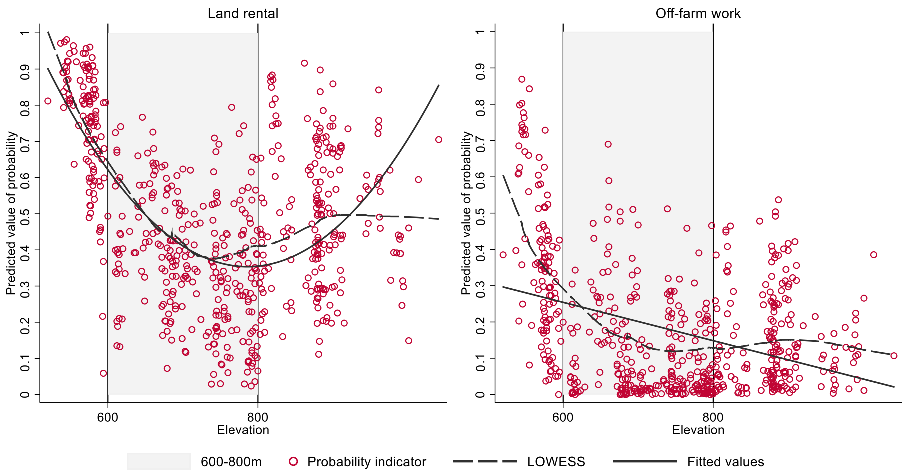
Variables	Off-farm (1 = yes; 0 = no) (1) Probit	(2) Probit	(3) Instrumental variable (IV) 2SLS model	(4) Recursive bivariate probit	(5) Marginal effects
Rent-out / Rent-out (IV)		0.170 (0.125)	0.481 (0.301)	0.863** (0.373)	0.327
Elevation groups					
Low (below 600 MASL)	0.325 (0.198)	0.283 (0.199)	0.022 (0.096)	0.127 (0.220)	0.050
Middle (600–800 MASL)	0.033 (0.149)	0.066 (0.150)	0.074 (0.068)	0.151 (0.153)	0.059
Labor	−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)	−0.0001
Material	−0.000** (0.000)	−0.000** (0.000)	−0.000* (0.000)	−0.000* (0.000)	−0.00003
Tree age	−0.028** (0.011)	−0.028** (0.012)	−0.008* (0.004)	−0.024** (0.012)	−0.009
Dai	−0.050 (0.130)	−0.084 (0.131)	−0.099 (0.067)	−0.194 (0.134)	−0.076
Household size	0.143*** (0.043)	0.129*** (0.044)	0.020 (0.022)	0.088* (0.049)	0.034
Age 16–40	0.003 (0.005)	0.003 (0.005)	0.002 (0.002)	0.002 (0.005)	0.001
Age 41–65	0.004 (0.004)	0.004 (0.004)	0.002 (0.001)	0.003 (0.004)	0.001
Education	0.168*** (0.033)	0.173*** (0.033)	0.040*** (0.012)	0.173*** (0.033)	0.068
Medium farm	−0.174 (0.153)	−0.173 (0.156)	−0.142* (0.072)	−0.267* (0.155)	−0.103
Large farm	−0.055 (0.181)	−0.141 (0.180)	−0.092 (0.079)	−0.242 (0.177)	−0.093
Assets middle 40%	−0.173 (0.124)	−0.159 (0.124)	−0.032 (0.048)	−0.100 (0.126)	−0.039
Assets top 10%	−0.073 (0.207)	−0.057 (0.210)	0.006 (0.081)	0.006 (0.214)	0.003
Land Gini	1.692*** (0.559)	1.748*** (0.565)	0.680*** (0.217)	1.830*** (0.571)	0.713
Village off-farm rate	0.017*** (0.004)	0.016*** (0.004)	0.004** (0.002)	0.012*** (0.004)	0.005
Plain	0.230* (0.130)	0.216* (0.131)	0.046 (0.058)	0.127 (0.139)	0.050
Distance	−0.002 (0.002)	−0.002 (0.002)	−0.000 (0.001)	−0.001 (0.002)	−0.001
Menghai	0.030 (0.194)	0.056 (0.195)	0.076 (0.080)	0.144 (0.192)	0.057
Jinghong	0.169 (0.146)	0.151 (0.146)	0.037 (0.056)	0.105 (0.147)	0.041
Constant	−2.150*** (0.503)	−2.163*** (0.502)	−0.311* (0.174)	−2.181*** (0.481)	
ρ_{eu}				−0.436* (0.230)	
ATT				0.270** (0.127)	
N	597	597	597	597	
Wald chi-sq	113.56***	114.90***		287.30***	
F-stat			7.90***		
Log likelihood	−340.97	−340.34		−682.41	
Wald test of exogeneity			2.45		
Wald test of $\rho_{eu} = 0$				2.71*	

Note(s): * indicates significance at the $p < 0.10$ level, ** at the $p < 0.05$ level and ***$p < 0.01$ level. Robust standard errors in parentheses significant in the probit model, which serves as the baseline (see column 2). The marginal effect of the land rental variable derived from the RBP model's estimates suggests that land leasing increases the probability of participating in off-farm works by 32.7%. We further employ bootstrapping to reduce the sampling noise, as suggested by Chiburis *et al.* (2012), and estimate the average treatment effects on the treated (ATT). This facilitates a better understanding of the effects of the land rental decision on off-farm work participation. The ATT coefficient in the RPB model indicates that land rental market participation significantly increases the probability of engaging in off-farm work by around 27%, which is lower than the land rental variable's marginal effect. By dealing with the problems of missing variable and sample selection bias in the RPB model, we can measure the causal effect of land rental decisions on the probability of entering the local labor markets in the context of declining rubber prices. We learn from the model results that land rental activities' contribution is significant in releasing the household labor and motivating the participation rate for off-farm employment as a coping strategy against the rubber price shock. The findings, therefore, support the third hypothesis.

In addition, the coefficient for material inputs and the average age of rubber trees are significant but negatively correlated with the off-farm work participation. In contrast, the coefficient of rubber labor input is not significant. This suggests that high input intensity rubber production reduces the probability of shifting to off-farm employment. Also, households with older rubber trees are less likely to participate in off-farm labor markets. The ethnicity Dai coefficient is only significant in the IV model and negatively correlated with the off-farm employment while the household size is significantly positive. Also, households with the better educational attainment of household heads are more likely to enter off-farm labor markets. Small-scale farmers are more likely to shift into the off-farm work than others endowed with the larger land area and households living in villages with highly skewed landholding. Furthermore, households in communities with a high participation rate in off-farm employment are more likely to select off-farm jobs.

Based upon the model estimates of Eqs (3.1) and (3.2), we plot the relationships between the elevation and the land rental and off-farm employment decisions using the approach of the locally weighted scatterplot smoothing (LOWESS) and fitted values of the probability of land rental and off-farm work participation (Figure 9). To better depict these probabilities' variations by different elevations level in XSBN, we use the continuous value of elevation rather than the discrete value of the elevation dummies that we regressed in the estimation. A U-shape relationship between the elevation and the land renting-out decision is observed. In the shadowed region indicating the middle-elevation areas ranging from 600 to 800 MASL, farmers encounter more barriers in renting out land than both the farmers living in the lowland and highland. Lower transferability of land-use rights leads to a lower probability of land rental in higher elevations. Another essential factor influencing this process is the sunk costs of rubber plantations, which acts as an entry barrier. It depicts an L-shape correlation between the continuous elevation and the predicted probability of working in the off-farm jobs. However, results must be interpreted with care since the elevation dummies' coefficients are not significant in the model estimation in the off-farm work equation. Farmers living in the lowland enjoy better opportunities to shift into off-farm employments, while farmers in highland do not. When viewing both graphs, we again observe that the farm households in the middle-elevation regions are less likely to adopt these coping strategies.

In summary, we find a *U*-shape type of relationship between rubber farmers' location and land rental coping strategy. More precisely, farmers in low elevation (below 600 MASL) have better access to off-farm labor and land rental markets. For farmers in high elevation (above 800 MASL) where rubber came in last, the possibilities of adopting other crops like tea are higher. On the other hand, their options are constrained due to limited opportunities for structural adjustment.



Note(s): The predicted value of probability in renting out land and participating in off-farm works are derived fromthe model estimates shown in column 5 of Table 4 and column 4 of Table 5, respectively

Figure 9. Association of elevation related to land rental and off-farm decisions

5.3 Robustness check – alternative model settings

One potential caveat is how the estimation results are dependent on the choice of the three elevation categories. We check the robustness of the results in both decision-making processes in land rental and off-farm work participation. The focus of the robustness check is on the estimation of the RPB model. Hereafter, several cases are considered:

(1) *Use of continuous values of elevation.* The form of the elevation variables may influence the results of model estimation. The continuous value of elevation and its squared term can more generally describe the relationship between the elevation and the decision of land rental and off-farm work participation.

(2) *Rubber path dependency.* The extent to which farmers depend upon rubber plantations may correlate with the farmers' decision-making in land rental and off-farm work participation and can influence the model estimation. Here we concentrate on farmers who specialize in rubber plantations. The specialized farm households who are more dependent on rubber plantations than others are less likely to enter the local land and labor markets, and therefore the location factors seem to play a weak role in their decision-making.

(3) *The age structure of the household.* The age structure of the household may correlate with the decisions about land rental and off-farm work participation. Farm households with a younger population structure may more likely lease out their land and move to off-farm occupations. Here, we focus on households with family members whose ages are below 65 years old.

The results are in line with our expectations (see Table 6). First, when using the continuous form of the elevation values, the results (see columns 1 and 2) remain consistent with those in Tables 4 and 5. Also, the results reflect a *U*-shaped correlation between elevation and land rental. Second, the coefficients of elevation are not significant in the model (see columns 3 and 4), suggesting that this location factor unlikely influences those rubber-

Table 6. Robustness check of the RBP model estimates for the decisions of land rental and participation in the off-farm labor market

Variables	Continuous value of elevation (1)	(2)	Rubber path-dependency (specialized farms) (3)	(4)	Age structure of the household (members below 65 years old) (5)	(6)
Rent-out (IV)		0.912** (0.397)		0.611 (1.440)		1.185*** (0.296)
Elevation	−0.025*** (0.007)	0.001 (0.007)				
Elevation sq	0.000*** (0.000)	−0.000 (0.000)				
Low (below 600 MASL)			0.627 (0.409)	0.709 (0.681)	0.897*** (0.261)	−0.092 (0.247)
Middle (600–800 MASL)			−0.267 (0.331)	0.544 (0.368)	−0.397** (0.172)	0.103 (0.174)
Selected instruments						
Land certification	0.370*** (0.129)		0.795*** (0.260)		0.313** (0.150)	
Perception on land tenure	0.335** (0.143)		0.025 (0.336)		0.533*** (0.166)	
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Constant	8.526*** (2.498)	−2.380 (2.729)	−1.514 (0.993)	−0.935 (0.898)	−1.219* (0.624)	−1.914*** (0.567)
N	597	597	240	240	425	425
Wald χ^2	277.51***		164.27***		285.73***	
Log likelihood	−691.60		−258.94		−466.77	
Wald test of $\rho_{\varepsilon u} = 0$	2.50		0.18		6.54**	

Note(s): * indicates significance at the $p < 0.10$ level, ** at the $p < 0.05$ level and ***$p < 0.01$ level. Robust standard errors in parentheses. All other control variables are included but not reported specialized farmers' decision-making processes in land rental and off-farm work participation. Locked within rubber plantations, those farmers have constrained options and opportunities. However, we note that this is probably an issue of small sample size. There are only 240 farm households who solely specialized in rubber plantations, and therefore, the result must be considered as suggestive only. Third, when looking at households with a younger age structure, we observe consistent results (see columns 5 and 6) compared to Tables 4 and 5 The coefficient of land rental decision becomes more extensive and more significant than that in Table 5. This implies that households with younger members tend to move out of their farms by leasing out their land and turn to off-farm employment. Hence, the effect of land rental on off-farm work participation is more remarkable.

5.4 Robustness check – sub-sample estimation

Estimations of models using the sub-sample farmers located in different elevation zones allow for evaluating the labor-release channel's diverse influences, especially for those in middle elevation. We add a robustness check using the RPB model estimates for land rental decisions and participation in the off-farm labor market at different elevation zones (see Table 7). We find that the land rental coefficient using the sub-sample located in the middle elevation zone is significant (see column 4). In contrast, respective coefficients in low and high elevation zones are not significant (see columns 2 and 6). The results again confirm the notion that farmers in the middle elevation zone can release labor to off-farm sectors if they can rent out land, which enhances their economic resilience to cope with the price shock.

6. Summary and conclusions

In this paper, we investigate the level of XSBN's smallholder rubber farmers' economic resilience under the condition of declining rubber prices. To facilitate our analysis, the smallholder rubber farmers' sample was split into three elevation levels, namely low elevation below 600 MASL, middle elevation between 600 and 800 MASL and high elevation above 800 MASL. We also investigate the role of prior investments in rubber plantations in the pathways out of the less profitable agricultural sector across the three elevation levels. Using statistical and econometric analyses, we tested three hypotheses.

The first hypothesis is that constrained by the existing investments in rubber plantations, farmers in the lower or higher elevation areas are more likely to lease out their land, while those in middle elevations are not. The results of the probit model confirm this proposition. As rubber prices continue to fall, renting out land is a viable ex-post coping strategy for the market shock. This is plausible because farmers who are renting out land can shift laborers to the off-farm sectors to supplement household income. Although both household groups, i.e., in the middle and the high elevations, face high costs of access to the land markets, the latter, as late adopters of rubber plantations, are less constrained in shifting land rental to other purposes. However, farm households located in the middle elevations are locked in a disadvantaged situation and are likely to be left behind.

Our results also support the second hypothesis that the farmers located in the low elevations gain a higher participation rate in the local labor market. The positive coefficients of the elevation variables estimated by instrumental variable and recursive bivariate probit models verify this notion. However, we cannot show a direct connection between elevation and off-farm labor market participation.

The third hypothesis that we have investigated is "engaging in off-farm job opportunities facilitates land rental market participation," and its re-enforcement effect, i.e. "access to land

Table 7. Robustness check of the RBP model estimates for the decisions of land rental and participation in the off-farm labor market at different elevation zones

Variables	Low (below 600 MASL) (1)	(2)	Middle (600–800 MASL) (3)	(4)	High (above 800 MASL) (5)	(6)
Rent-out (IV)		0.937 (0.572)		1.658*** (0.119)		0.817 (1.285)
Selected instruments						
Land certification	0.654 (0.423)		0.248 (0.158)		0.607*** (0.234)	
Perception on land tenure	8.166*** (0.662)		0.340** (0.135)		0.479 (0.303)	
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−1.107 (1.401)	0.745 (1.323)	−1.961*** (0.593)	0.114 (0.550)	−1.417 (1.270)	−5.225*** (1.375)
N	121	121	277	277	199	199
Wald χ^2	2384.63***		258.11***		111.69***	
Log likelihood	−102.72		−301.60		−221.63	
Wald test of $\rho_{\varepsilon u} = 0$	2.32		3.94**		0.11	

Note(s): * indicates significance at the $p < 0.10$ level, ** at the $p < 0.05$ level and ***$p < 0.01$ level. Robust standard errors are in parentheses. All other control variables are included but not reported rental markets releases free laborers for off-farm work participation." The empirical analysis testifies the latter procedure. Under the shock of declining rubber prices, the incomes of the rubber smallholders go down. They temporarily suspend management care of rubber or even leave out of rubber farming and take some part-time off-farm job activities with low wage rates.

In a nutshell, the lesson from this study is that location plays a significant role in rural development and, to a large extent, determines small-scale rubber farmers' economic resilience under income shocks. Our findings are likely to be valid not for XSBN but also other similar situations in China. The extensive investment in rubber plantations in the past enhances location significantly when economic conditions change. The past's high rubber prices have misguided farmers to plant rubber in areas that are less suitable for this crop, namely, the higher elevations. Their yield is low, and the rubber is only economically feasible conditional on the high prices for latex and dried rubber. Higher elevations are also those where infrastructure like roads and access to factor and output market is still underdeveloped. Yet, the land is abundant, and the possibility to diversify to other crops such as tea exists. In contrast, rubber farmers in low elevations are better endowed and, therefore, more easily participate in off-farm labor and land rental markets. Curiously, farmers located in middle elevations seem to be locked into rubber farming. This can be explained by the fact that often they have become specialized in rubber farming but are constrained by limited access to land rental and off-farm labor markets. Our policy message, therefore, is that policy interventions need to take into account location factors. Blanket government support programs are likely to be dysfunctional and impede a socially optimal transformation path and weaken farmers' economic resilience.

This study complements the existing literature on off-farm employments and land rental behavior as well as the rural nonfarm economy in China (e.g. Che, 2016). It also has important implications that can improve the understanding of the coping strategies and economic resilience of farmers planting tree crops with long production periods under external shocks. We provide insights that the geographical location is key to proxy both the costs of land use adjustments and access to local markets. At the same time, we investigate how and to what extent the location can hinder a specific, less-favored farmer group to offset the agricultural risks.

On the other hand, while this study is limited to southern China, the findings have practical reference implications for advancing the knowledge about the under-developed, remote and mountainous rural areas in China inhabited by indigenous ethnic minorities. The lagging poor ethnic-minority regions in Yunnan Province are one of the policy focus of China's national poverty reduction strategy. To some extent, this study contributes to understanding the nature and causes of poverty with typical geographical conditions and economy tied on the narrow agricultural income source. This study's findings assist policy-making on rural development and poverty reduction, especially in rural areas stricken by chronic and persistent poverty [9].

Undeniably, the study has some limitations. The major caveat is using a cross-sectional dataset that is unable to capture the dynamics of and changes in farmers' activities of land rental and off-farm employment participation. Hence, further research that can use a later panel wave of the XSBN dataset will advance the findings of this study and provide lessons on the long-term rural transformation process [10].

Notes

1. Notably, the farmland above 950 MASL is no more suitable for rubber plantations due to its poor natural conditions (Agricultural Reclamation Bureau of Yunnan Province, 2003). Very rarely did the rubber plantations expand up to the zone above 950 MASL.
2. Here, the downsides are twofold (1) the less care-intensive activities on land management (e.g. water management and fertilizer application) leads to lower productivity and (2) the smaller amount of labor used on land increase the risk of loss of land that is reallocated by the local government.

3. Though the farmers' schooling may, to some extent, capture their capacity and skills, it is not possible to control for all such potentially confounding factors, such as the skills gained from the informal training experiences in the farmer field schools.
4. We apply an ordinary least square (OLS) estimation of the linear probability model (LPM) with instruments, namely the instrumental variable 2SLS model (IV-2SLS). The IV-2SLS is applied to address the endogeneity issue and facilitate several tests to examine the validity of the instruments. However, we recognize that the binary dependent variable may encounter the limitations of LPM. Therefore, the main results regarding the effects of land rental on the off-farm employment participation are drawn from the recursive bivariate probit model. At the same time, the LPM serves as a reference.
5. In the field survey, a sum of 612 smallholder farmers of Xishuangbanna (XSBN) was sampled. Among these smallholder farmers, we took out 15 samples (2% of the total sample) from a nontypical village dominated by ancient tea (i.e. gu-shu-cha, in Chinese) enjoying much higher price rates compared to other teas. We reckon that samples from this village are not typical rubber farmers and encounter few livelihood problems derived from the rubber dependency under declines in rubber prices.
6. In our latest round of field survey in XSBN, the issuance of new land certificates had not been completed until the end of 2018.
7. As the commodity price of rubber continues to decline as well as the rising off-farm job opportunities, farmers, mostly the younger laborers in the household, are increasingly shifting to off-farm sectors. The inadequate household labor and investments constrain farmers' activities on land management and agricultural productions. On the other hand, the land and natural conditions are suitable for the development of crop cultivation, and the land rents are relatively low compared to that of economic development hotspots in China. Though land transitions in XSBN, outside private investors and agricultural enterprises rent the land to cultivate cash crops and tropical fruits. As a consequence, local agriculture and its varieties are commercialized.
8. The rubber trees above 800 MASL are not yet available for tapping (or harvesting), on average, given the young age of trees.
9. The reduction of chronic and persistent poverty in the remote and minority rural areas in China, known as "san-qu-san-zhou", is the core of this national strategy. These regions are mainly located in the Qinghai–Tibet Plateau with deplorable natural and economic conditions.
10. The latest wave of the survey of the rubber smallholders in XSBN was conducted in March 2019. The dataset is not yet available for this paper but will be considered in future studies.

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Appendix

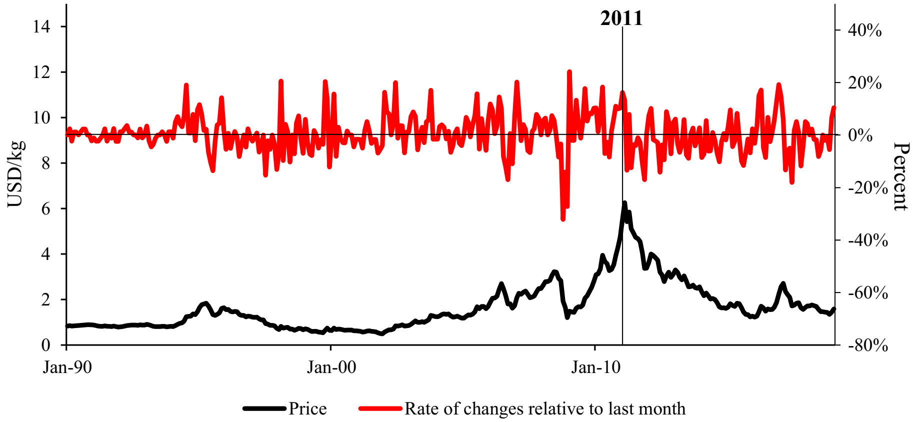

Figure A1. Monthly rubber commodity price and its volatility

Source(s): Singapore Commodity Exchange (SICOM), 2019

Variables	Description and definition	Elevation zones: Low-elevation (below 600 MASL) (N = 121)	Middle-elevation (600–800 MASL) (N = 277)	High-elevation (above 800 MASL) (N = 199)
Dependent variables				
Off-farm	Household with members engaging in any off-farm employment (1 = yes; 0 = no)	0.529 (0.501)	0.394 (0.489)	0.387 (0.488)
Rent-out	Household with rent-out land (1 = yes; 0 = no)	0.760 (0.429)	0.365 (0.482)	0.492 (0.501)
Independent variables				
Labor	Family labor inputs in rubber farming (person day)	391.3 (520.4)	436.1 (1046.0)	265.6 (226.7)
Material	Material and other inputs in rubber farming (USD)	713.8 (2614.2)	826.1 (1617.1)	982.0 (1196.6)
Tree age	The average age of rubber trees (years)	16.06 (5.874)	13.03 (6.073)	10.88 (4.647)
Dai	Dai household (1 = yes; 0 = no)	0.760 (0.429)	0.606 (0.489)	0.482 (0.501)
Household size	Household size (persons)	5.397 (1.497)	5.394 (1.475)	4.950 (1.413)
Age ≤ 15	% of household members (age ≤ 15)	16.95 (14.11)	20.30 (14.94)	19.71 (15.15)
Age 16–40	% of household members (15 < age ≤ 40)	42.33 (13.06)	42.80 (15.19)	42.51 (15.79)
Age 41–65	% of household members (40 < age ≤ 65)	34.11 (15.41)	30.11 (16.38)	30.95 (19.50)
Age ≥ 66	% of household members (age > 65)	6.613 (10.94)	6.795 (12.57)	6.831 (13.15)
Education	Average schooling years of household members (years)	4.543 (1.824)	4.731 (3.115)	5.020 (2.005)
Small farm	Household land area per capita at the smallest 1/3 (1 = yes; 0 = no)	0.455 (0.500)	0.325 (0.469)	0.276 (0.448)
Medium farm	Household land area per capita at the medium 1/3 (1 = yes; 0 = no)	0.397 (0.491)	0.267 (0.443)	0.377 (0.486)
Large farm	Household land area per capita at the largest 1/3 (1 = yes; 0 = no)	0.149 (0.357)	0.408 (0.492)	0.347 (0.477)
Assets bottom 50%	Household asset per capita at the bottom 50% (1 = yes; 0 = no)	0.322 (0.469)	0.477 (0.500)	0.628 (0.485)
Assets middle 40%	Household asset per capita at the middle 40% (1 = yes; 0 = no)	0.504 (0.502)	0.408 (0.492)	0.327 (0.470)
Assets top 10%	Household asset per capita at the top 10% (1 = yes; 0 = no)	0.174 (0.380)	0.116 (0.320)	0.0452 (0.208)
Gini	Gini coefficient of land endowment in the village	0.345 (0.155)	0.307 (0.108)	0.292 (0.0551)

(*continued*)

Table A1. Variable definition and descriptive statistics

Variables	Description and definition	Elevation zones Low-elevation (below 600 MASL) ($N = 121$)	Middle-elevation (600–800 MASL) ($N = 277$)	High-elevation (above 800 MASL) ($N = 199$)
Village off-farm rate	Village off-farm rate (%)	16.86 (11.50)	15.23 (22.73)	8.487 (6.728)
Land flatness	Village in flat region (1 = yes; 0 = no)	0.463 (0.501)	0.282 (0.451)	0.482 (0.501)
Distance	Distance from community to county (km)	41.83 (10.99)	80.34 (49.15)	77.98 (31.51)
Menghai	County of Menghai (1 = yes; 0 = no)	–	0.177 (0.382)	0.176 (0.382)
Jinghong	County of Jinghong (1 = yes; 0 = no)	0.455 (0.500)	0.375 (0.485)	0.598 (0.492)
Mengla	County of Mengla (1 = yes; 0 = no)	0.545 (0.500)	0.448 (0.498)	0.226 (0.419)
Instrument variables				
Land certification	Household land entitled to both farmland and forestland tenure certificates (1 = yes; 0 = no)	0.306 (0.463)	0.245 (0.431)	0.307 (0.462)
Perception on land tenure	Land tenure certificates believed to be extended when expired in the future (1 = yes; 0 = no)	0.132 (0.340)	0.220 (0.415)	0.176 (0.382)

Source(s): Authors' survey

Table A1.

Variables	Rent-out (1 = yes; 0 = no) IV-2SLS	RBP
Elevation groups		
Low (below 600 MASL)	0.630*** (0.212)	0.618*** (0.210)
Middle (600–800 MASL)	−0.349** (0.142)	−0.373*** (0.144)
Labor	−0.000 (0.000)	−0.000 (0.000)
Material	−0.000 (0.000)	−0.000 (0.000)
Tree age	−0.010 (0.011)	−0.009 (0.012)
Dai	0.456*** (0.127)	0.455*** (0.126)
Household size	0.145*** (0.043)	0.143*** (0.043)
Age 16–40	0.000 (0.005)	0.001 (0.005)
Age 41–65	0.002 (0.004)	0.002 (0.004)
Education	−0.033 (0.026)	−0.033 (0.026)
Medium farm	0.498*** (0.154)	0.461*** (0.154)
Large farm	0.500*** (0.182)	0.485*** (0.179)
Assets middle 40%	−0.257** (0.122)	−0.248** (0.122)
Assets top 10%	−0.294 (0.196)	−0.299 (0.195)
Land Gini	−0.564 (0.562)	−0.645 (0.570)
Village off-farm rate	0.010*** (0.004)	0.011*** (0.004)
Plain	0.368*** (0.133)	0.359*** (0.133)
Distance	−0.002 (0.002)	−0.002 (0.002)
Menghai	−0.459** (0.194)	−0.479** (0.194)
Jinghong	0.185 (0.149)	0.154 (0.152)
Land certification	0.335*** (0.131)	0.336*** (0.129)
Perception on land tenure	0.372*** (0.145)	0.408*** (0.141)
Constant	−1.070** (0.503)	−1.021** (0.500)
N	597	597
Wald test on selection instruments (*F* statistic)	14.04***	17.04***
Underidentification test		
Kleibergen-Paap rk LM statistic	12.60***	
Partial R^2 of excluded instruments	0.0212	
Test of excluded instruments (*F* statistic)	6.36***	
Weak identification test		
Conditional likelihood ratio test	6.36*	
Overidentification test of all instruments		
Hansen *J* statistic	0.81	
Goodness-of-fit tests		
Murphy's score test		9.94
Hosmer–Lemeshow test		14.11

Note(s): * indicates significance at the $p < 0.10$ level, ** at the $p < 0.05$ level and ***$p < 0.01$ level. Robust standard errors in parentheses
The result of the Wald test of exogeneity in the IV model does not support the existence of endogeneity of land rental decisions. However, In the RBP model, the Wald test of $\rho_{\varepsilon u} = 0$ has been rejected at the 10% significance level, where $\rho_{\varepsilon u}$ stands for the correlation coefficient between the residuals in the equations, indicating that the hypothesis "land rental decision is exogenous" cannot be confirmed. It suggests the presence of a selection bias arising from unobserved factors. In particular, the negative correlation coefficients $\rho_{\varepsilon u}$ show negative selection bias, suggesting that farmers having lower probabilities of getting engaged in off-farm employment are more likely to rent out land. This is because farmers who lack off-farm income sources rent out land to smooth their household income in coping with the rubber price shocks. Besides, maximizing the joint density of the observed dependent variables in the RBP model does not guarantee a good fit. We, therefore, include both Murphy's score test and Hosmer–Lemeshow's test to check the misspecification of the RBP model. The null hypothesis of Murphy's score test is that the error terms in Eqs (3.1) and (3.2) are bivariate standard joint normal. And the null hypothesis of the Hosmer–Lemeshow test is that the sampling frequency of the dependent variable and the fitted probability of the observation sub-group are identical. The p-values are all not significantly different from zero at the 10% level, which indicates that the null hypothesis of normality cannot be rejected. Therefore, the RBP model fits well with our dataset

Table A2. The first-stage regressions of IV-2SLS and RBP models

Table A3.
Exogenous test for the instrumental variables

Variables	Off-farm (1 = yes; 0 = no)
Land certification	−0.040 (0.116)
Perception on land tenure	0.172 (0.132)
Control for other variables	Yes
Constant	−0.227*** (0.065)
N	597
Wald test on selection instruments (*F* statistic)	1.78

Note(s): * indicates significance at the $p < 0.10$ level, ** at the $p < 0.05$ level and ***$p < 0.01$ level. Robust standard errors are in parentheses

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