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Risk preferences significantly affect household investment in timber forestry: Empirical evidence from Fujian, China

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ABSTRACT

Implementing another round of massive collective forest tenure reform in China since in 2008 has not materialized the government's expectation on small-scale timber forestry-improved management practices and resource quality. One underlying cause to this outcome is farmer's risk-averse attitude, which has thus far garnered little research attention. In this study, we combine the prospect theory and a lottery experiment to measure individual risk preferences on timber forestry investment. Based on a sample of 303 households conducted in 2018 in Fujian, China, we find that the 'household risk preference' parameter has a significant negative impact on both the decision to invest in timber forestry and the intensity of investment. Further, the 'loss aversion' and 'probability weighting' parameters affect household investment intensity negatively. These results indicate that the more risk averse rural households are, the less willing they are to invest in timber forestry, and the lower their investment intensities are. Also, the effect of the risk preferences on cash outlay is larger than on labor cost. These insights have direct implications for better designing tenure reform and other policies to promote smallholder forestry in China and beyond.

1. Introduction

Forest tenure reform through decentralization has been implemented in many developing countries throughout the world (Robinson et al. 2014; Yin 2016; Gebara 2018). Some studies have reported positive impacts of the reform on forestry investment in countries like Ghana and Ethiopia (Holden et al. 2009; Sullivan et al. 2018), while others find that the attempts at decentralization did not work as expected, leading to rampant illegal logging and exacerbated deforestation in Russia and Indonesia (FAO, 2012). China's more recent experience with forest tenure reform has provided a new opportunity to assess its impact, with significant national and global policy implications.

In China, forestland ownership falls into two broad classes: collective or state-owned. Collective forestland was until recently mostly managed by rural communities (i.e., villages), and as of 2015 amounted to 180

million ha, or 60.1% of the nation's total (Liu et al. 2016). However, these collective forests generally had low growth rates, stocking levels, and poor stand quality (Yin et al. 2013). Against this backdrop, the central government initiated a new round of reforms in 2008 by transforming the collective forest control into family-based management.¹ By the end of 2016, 98% of collective forests had been allocated to households (SFA, 2017). Hence, the sustainable management of small-scale forests controlled by households is crucial to realizing national timber production and conservation goals.

The collective forest tenure reforms aimed to create new incentives and benefits for over 500 million farmers to enhance forest growth and quality through improved management practices (Krul et al. 2020). In theory, the enthusiasm for forestry management among rural households was expected to have increased substantially following the reforms. While the cultivation and collection of non-timber forest products

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¹ These new reforms (commonly called collective forest tenure reforms) consist of the following components: a) clarifying property rights by allocating collective forestland to farmers, demarcating the land plot boundaries, and providing certificates of land-use rights; b) guaranteeing management rights, wherein farmers can make decisions about their operation of commercial forests; and c) granting to farmers the rights of disposing and transferring forests and trees, as well as receiving compensation once their forests are taken for public purposes (Yin et al. 2013).

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(NTFPs) has been expanding rapidly (Liu et al. 2016; Ke et al. 2020), actions taken by households to engage in timber-oriented forest management have not improved much (Hyde 2019). According to official statistics, the productivity level of collective forests is only 75% of the national average, and the mean stock volume of collective forests is only 29.1m³ per ha, far below the world average (90 m³) (SFGA 2019). This outcome is deemed largely to have resulted from the lower-than-expected investment efforts and thus the lack of effective management practices (Liu et al. 2016; Hyde and Yin 2019).

Forest economists have attempted to explain the lower-than-expected individual investments in collective timber forestland, and several fairly consistent, and often overlapping, findings have emerged. They include: (1) the large-scale exodus of rural labor has weakened forest investment due to labor shortages and higher wage rates (Liao et al. 2015; Duan et al. 2017); (2) the extensive parcelization of forestland, driven by allocating small tracts to households, has led to diseconomies of operations and raised management costs (Xie et al. 2014; Huang et al. 2019); (3) the strict harvesting regulation² has dampened households' desire for forest investment (Miao and West 2004; He et al., 2016); (4) the remaining credit constraints have not been effectively relaxed, thus reducing the attraction of investing in forest management (Xie and Zhi, 2011; Uusivuori and Kuuluvainen 2001); and (5) severe market distortions caused by the imposition of price control and taxes and fees on timber sales were reduced and finally removed only a short while ago (Li et al. 2021).

These explanations are incomplete, however. Timber production has the inherent characteristics of long rotation and, therefore, long-term investment and high risk. In fact, some scholars have argued that the lower-than-expected investment is partly caused by household's acute concern with the risks and uncertainties involved in their forest management and future rewards from it. In addition to likely natural factors, the risks and uncertainties have much to do with the policy instability (e. g., logging restrictions imposed everywhere and complete bans in naturally regenerated forests³), the fluctuation of timber prices, and rights disputes (Yin and Newman 1997; Chen and Ke 2017; Zhang and Huang 2016). These factors are heavily predicated on the individuals' attitudes towards risks.

There is an extensive amount of literature on how households' risk preferences affect livelihood decision-making (Ajzen and Ishbein 1977; Just and Zilberman 1983; Knight et al. 2003). It is commonly viewed that households with a higher degree of risk aversion are less likely to increase inputs; as a result, their production decisions often deviate from economically efficient outcomes. In terms of timber management, many studies agree that risk-averse forest owners choose shorter rotations (e. g., Caulfield 1988; Gong 1998; Gong and Lofgren 2003). Furthermore, Lien et al. (2007) found that the degree of risk aversion would affect forest owners' replanting strategies and forest investment decisions. In a study in Zhejiang Province, China, Zhu et al. (2015) demonstrated that risk-averse households were willing to follow the traditional management practices on land plots they held, while the less risk-averse ones were more willing to engage in forestland rent-in to expand the scale of their operations.

In short, few empirical analyses have focused on the linkage between household risk preferences and their forestry investment decisions. Nevertheless, given the basic characteristics of forest management—long term and high risk, whether the households' risk preferences play

an important role on their forest investment decisions should be carefully investigated. Furthermore, most empirical inquiries into the linkage between forestry decision-making and risk preference are based on the expected utility function, where risk aversion is the canonical parameter that determines the curvature of the utility function. In the prospect theory (PT) (Kahneman and Tversky 1979), however, the shape of the utility function is jointly determined by risk aversion, loss aversion (measuring one's sensitivity to loss compared to gain), and non-linear probability weights (i.e., the individual tendency of over-weighting small probabilities and underweighting large probabilities). As such, it is generally understood that the prospect theory better captures rural households' risk preferences than the expected utility theory. In this study, therefore, we measured individual's risk preferences based on the prospect theory. Experimental economists have developed a variety of methods to measure risk preferences more properly (Binswanger 1980; Holt and Laury 2002; Tanaka et al. 2010). Thus, in this study we elicited rural households' risk preferences from a lottery experiment.

The objective of this study is thus to explore the impacts of household risk preferences on forest investment decisions. Here, our focus is on the role of individual risk preferences towards the intensity of various forms of investment (capital and labor) in different management phases (from planting to tending and thinning). To pursue this objective, we first executed a detailed household questionnaire jointly with a field experiment in Fujian in 2018—10 years after the introduction of the new forest tenure reform. We then built a double-hurdle model to estimate the effects of measured risk preferences on forest investment decisions. The rest of this paper is organized as follows. We describe our theoretical and empirical models and data in sections 2–4, and then present and discuss our estimated results in section 5. Finally, closing remarks are made in section 6.

2. Theoretical model

In this section, we construct a static household model to explore farmers' forestry investment decisions. Consistent with what has been reported in the literature, we assume that Chinese forestland managers are risk-averse in uncertain situations. Their investments include forestry investment and non-forestry investment. Suppose that the initial capital for each forest owner X is W , and each forest owner has N kinds of investment choices, the unit benefit of n th investment (I_N) is Z_N , and the joint distribution of the benefit conforms to the function $F(Z_1, \dots, Z_N)$. Then, the total utility of the investment portfolio ($I_1, \dots, I_N$) is $U(I_1, \dots, I_N) = \int u(I_1 Z_1 + \dots + I_N Z_N) dF(Z_1, \dots, Z_N)$, where U represents the total utility of all forestry investment, and $U(I_1, \dots, I_N)$ is increased by degrees concave function (Andreu et al. 1995).

Consider two forest owners (where $i = A$ or B) with different risk preferences measured by $R(\cdot)$. The optimal forestry investment amount is expressed by I_A^* and I_B^* respectively, and the corresponding utility is $u_A(x)$ and $u_B(x)$, respectively.

The optimal decision of a forest owner's forestry investment behavior is as follows:

$$\max_{0 \leq I \leq W} \int u_i(W - I_i + I_i Z) dF(Z) \quad (1)$$

If there exists an optimal investment, the first-order condition needs to be satisfied:

$$\varphi_i(I_i^*) = \int (Z - 1) u_i'(W_i + I_i^* [Z - 1]) dF(Z) = 0 \quad (2)$$

According to the Arrow-Pratt hypothesis, when given utility function $u(\cdot)$, the risk aversion coefficient at point x is defined as $R(x) = -\frac{u''(x)}{u'(x)}$. We always have $u_B(x) = f(u_A(x))$ for some increasing function $f(\cdot)$; this is true simply because $u_A(x)$ and $u_B(x)$ are ordinally identical (more money is preferred to less) (Andreu et al., 1995). Combined with formula (2), we have:

² Logging regulation in China's forest sector began in 1987. Annual harvesting quotas have been controlled by the government. Anyone who wishes to cut trees must apply for a logging permit within the given quota. Harvesting quotas are revised every five years (He et al. 2016).

³ Logging in natural forests has been prohibited in the Northeast since 2015, and this restriction was extended to the entire country in 2017. This occurred despite the very limited number of natural forests in the southern collective forest region and other areas (Ma et al. 2020).

$$\varphi_B(I_A^*) = \int (Z-1)f'(u_A(W+I_A^*[Z-1]))u_A'(W+I_A^*[Z-1])dF(Z) \quad (3)$$

For formula (3), we can take the different expressions $u_B'(x) = f'(u_A(x))u_A'(x)$ and $u_B''(x) = f''(u_A(x)) + f''(u_A(x))(u_B'(x))^2$. Then combining the two different expressions, we can get $R(x, u_B) = R(x, u_A) - \frac{f''(u_A(x))}{f'(u_A(x))}u_A'(x)$. Therefore, $R(x, u_A) \leq R(x, u_B)$ is valid for all x , if and only if there is $f''(u_A(x)) \leq 0$ for all u_A in the value range $u_A(\cdot)$, therefore function $f(\cdot)$ is concave. And $f'(\cdot)$ is positive and decreasing, i.e. $f'(u_A(W+I_A^*[Z-1]))$ is positive and decreasing. Compared to the negative value $(Z-1)u_A'(W+I_A^*[Z-1])$ ($Z < 1$), the weight of the positive value ($Z > 1$) is shrinking. In eq. (3), the sum of the positive part and negative part in the integrand is 0, then:

$$\varphi_B(I_A^*) = \int (Z-1)f'(u_A(W+I_A^*[Z-1]))u_A'(W+I_A^*[Z-1])dF(Z) < 0 \quad (4)$$

Comparing formula (2) and formula (3), it can be seen that the integrand of formula (4) is the same as the integrand of formula (2), except for multiplying the function $f'(u_A(W+I_A^*[Z-1]))$. When comparing formula (2) with formula (4), we can conclude that if the risk aversion of $u_A(\cdot)$ is lower than that of $u_B(\cdot)$, then $I_B^* < I_A^*$, indicates that the higher risk aversion forest owner would invest less in forestry production.

The above model suggests that farmers' risk aversion level would affect their forestland investment decisions. This theoretical proposition can be tested through an empirical analysis. But it is difficult to do so because individual risk attitudes cannot be directly observed using a typical household survey. In this study, therefore, we first elicited rural households' risk preferences from a lottery experiment, following the design developed by Tanaka et al. (2010) and Liu (2013). We then included the experimental risk responses in assessing their forestry decision-making.

More specifically, three coefficients were used to represent individual risk preferences: i) risk aversion coefficient σ , ii) loss aversion coefficient λ , and iii) probability weighting parameter α (also known as "subjective weighted probability"). If estimates from the lottery experiment give us $\alpha = 1$ and $\lambda = 1$, the model outlined below would reduce to an EU one. However, if $\alpha < 1$ and $\lambda > 1$, the PT theory is a more appropriate model than the EU theory.

With the lottery selection experiment, the utility model for calculating the risk preference is as follows:

$$U(x, p; y, q) = \begin{cases} v(y) + \pi(p)[v(x) - v(y)], & x < y < 0, \text{ or } x > y > 0 \\ \pi(p)v(x) + \pi(q)v(y), & x < 0 < y \end{cases} \quad (5)$$

$$\text{where } v(x) = \begin{cases} x^{(1-\sigma)}, & x < 0 \\ -\lambda(-x)^{(1-\sigma)}, & x \geq 0 \end{cases} \quad (6)$$

$$\pi(p) = \exp[-(-\ln p)^\alpha] \quad (7)$$

Here, x, y represents the payoff outcomes, p, q represents the probability of the outcomes, $U(x, p; y, q)$ indicates the expected prospect value, and $v(x)$ indicates the power value function (Liu 2013). The risk aversion parameter σ indicates the curvature of the individual's value function. The respondents are depicted as risk-seeking if $\sigma < 0$, risk-neutral if $\sigma = 0$, and risk-averse if $\sigma > 0$. The loss aversion parameter λ describes the curvature of personal value function larger than zero relative to the curvature of the value function less than zero, representing the individual's sensitivity level to the loss compared to the same-scale profit. The higher λ means that an individual is more loss averse. The probability weighting parameter α is indicated by the function $\pi(p)$ (Prelec, 1998). When $\alpha = 1$, $\pi(p)$ is a linear function, when $\alpha < 1$, $\pi(p)$ indicates an inverted S-type, which means that an individual overweighs the low probabilities or underweighs the high probabilities (Tversky and Kahneman, 1991). A detailed description of the

experiment and the calculation of risk preference parameters is shown in Appendix A, and a record sheet of the experiment is provided in Appendix B.

3. Empirical specification

Although household decision-making with regard to timber production investment might have some general tendencies for all plots (given their general risk preferences), there is nonetheless variation between different plots (due to plot-level biophysical features). Therefore, we did an analysis of the factors influencing household timber production investment decisions at the plot level. Household investment decisions are governed by a set of variables, including those pertaining to the socio-economic circumstances, the characteristics of the forest plot itself, and policy constraints (Zhang and Owiredun 2007; Yi et al. 2013; Zhu et al. 2019). Thus, we developed the following model to assess the impacts of household risk preferences on forest investment:

$$\ln(\text{finvest}_{ij}) = \beta_0 + \beta_1(\text{risk}_i) + \beta_2(\text{loss}_i) + \beta_3(\text{probweight}_i) + \sum P + \prod X_i + \Omega F_j + V_v + \varepsilon_{ij} \quad (8)$$

where finvest_{ij} represents the total investment of household i in plot j ; risk_i is the risk aversion parameter, loss_i the loss aversion parameter, and probweight_i the probability weighting parameter derived from the field experiment; P represents policy constraint variables, including forest type in the plot (by asking whether the plot was taken for environmental purposes) and forest tenure security (by asking whether the plot has an official certificate); X_i represents household socio-economic variables, including age, education, and health condition of household head, number of household members with off-farm employment, and credit constraints (whether the household are able to successfully borrow money within one week); F_j reflects for forest plot characteristics, including area, slope, soil quality, age of stand, the distance to home and road, and the total number of plots (to measure forest plot parcelization); V_v is the village fixed effect; and ε_{ij} is the error term.

The dependent variable—timber production investment—can take a value of 0. This is known as censoring in the literature (Tobin 1958). Consequently, the use of ordinary least squares (OLS) can result in bias estimation errors. One way of resolving this problem is to use the classic Tobit model. However, the limitation of the Tobit model is that it assumes that the same variables affect the probability of a non-zero observation (the participation decision) as well as the level of a positive observation (the intensity decision), and with the same sign, as well. It may be more reasonable to allow the size and nature of the factors that affect the two decisions to differentiate. As a result, a number of generalizations to the Tobit model have been developed. One generalization popular in the literature is the double-hurdle model (Cragg 1971). The double-hurdle model is specified as follows (Blundell and Meghir 1987; Newman et al. 2003).

$$y_{i1}^* = w_i'\alpha + v_i \text{ Participation decision} \quad (9)$$

$$y_{i2}^* = x_i'\beta + u_i \text{ Expenditure decision} \quad (10)$$

$$y_i = x_i'\beta + u_i \text{ if } y_{i1}^* > 0 \text{ and } y_{i2}^* > 0 \quad (11)$$

$$y_i = 0 \text{ otherwise} \quad (12)$$

where y_{i1}^* is a latent variable describing the household's decision to invest in forest plots, y_{i2}^* is a latent variable describing household forest investment intensity, y_i is the observed dependent variable (household investment in forest plots), w_i is a vector of variables explaining the participation decision, x_i is a vector of variables explaining the intensity decision, v_i and u_i are the respective error terms assumed to be independent and distributed as $v_i \sim N(0,1)$ and $u_i \sim N(0, \sigma^2)$.

Another common approach to treating the censored data is to use a

two-stage estimation method to correct the sample selection bias and before fitting the ordinary regression model (Heckman 1979). However, this approach is designed for incidental truncation with zeros being unobserved values, such as in the case of wage rate models where the sample includes unemployed persons. A corner solution model is thus more appropriate than a selection model for our study because many households chose not to invest due to internal and external conditions. That is, a zero investment in the data reflect household's choice rather than representing a missing value. In addition, the Heckman model assumes that zeros arise due to non-participation only; once a household participates (passes the first hurdle), then zero investment is not possible. In contrast, the double-hurdle model assumes that zeros can arise at both the first stage (participation vs. non-participation) and the second stage (investment vs. non-investment).

To alleviate the potential heteroscedasticity, the double-hurdle model was estimated using the bootstrap estimation procedure. Recognizing that households may have a similar investment strategy in their different plots (given their general risk preference behavior), we chose the standard error to cluster at the household level in our estimation. We further re-estimated our model at the household level rather than plot level in our robustness check to avoid the correlation of the error terms.

4. Data collection and description

Sanming City in Fujian Province was selected as the research site for this study. Fujian is one of the key collective forest areas in China, being the first province to carry out collective forest tenure reform starting in 2002. The forest area of Fujian was 17.6 million ha in 2018, and the forest coverage rate was 77%, ranking as the highest in China (SAFG, 2019). In Fujian, forests are crucial to local livelihoods, especially for those individuals living in mountainous areas who have a high dependency on forest products (Qin and Xu 2013).

Our field experiment and data collection were carried out in February 2018. The team members were social science graduate students with considerable research interest and some field experience. Before conducting the household survey, they had training in research methods and data collection. The study sample was selected through a three-stage process following that of Qin (2010). First, four counties were chosen according to two criteria: (1) a high level of family forest management; and (2) abundance of forests. These criteria manifest the relationship between family forest management decisions and the rural forest resources, and thus are conducive to our understanding of decision making by small-scale forest owners. Second, we divided the villages into high and low income groups in each chosen county, with two villages randomly selected in each group. Third, sample households were designated using a random drawing (Singleton and Straits 2005). With the assistance of village representatives, 20 households were selected randomly in each village. Altogether, a total of 320 households from 16 villages were sampled, and 303 questionnaires were properly executed, with information captured for 1352 forest plots. This three-stage sampling procedure has helped capture the social, economic, and biophysical diversity and heterogeneity across rural households in Fujian.

The household survey was conducted to collect information about rural livelihood activities based on a structured questionnaire. The questionnaire contained questions on household demography, assets, and agricultural and forestry activities. The surveyed individuals, mostly household heads, within the villages completed the questionnaire themselves on-site, with our team's assistance. Some of the selected households dropped out of the survey because they thought the interviews were too time-consuming (the average time was 40 min) or the questions were too sensitive. Along with household surveys, we conducted a lottery selection experiment (Fehr and Goette 2007; Liu 2013) to identify and measure the respondents' risk preferences. After the questionnaires were completed, our research team crosschecked the outcomes to ensure data quality.

Given that the focus of this study is on farmers' investments in timber production, those forest plots used mainly for generating non-timber forest products were not included. Derived from the questionnaire data, investment in timber production is an aggregation of all relevant cash expenses and labor costs on each plot since the tenure reform (namely during 2008–2017). Cash expenses refer to the outlays used for tree planting and stand tending, including land rental and purchases of chemical fertilizer, pesticide, and seeds. Labor costs refer to the values of labor time allocated to tree planting and forest tending, including family own and hired labor. We obtained the labor costs by multiplying total days of labor input by average daily wages. Expenditures incurred during the harvesting phase were excluded in our timber production investment since most of the sample households did not harvest timber themselves; they usually auctioned their harvesting rights to others. As investment in timber production occurred over time, we converted the nominal values into 2018 real terms using China's rural consumer price index (CPI).

Table 1 presents the descriptive statistics of the variables used in this study. Total investment in timber forestry of sample households is 5866.47 yuan/ha on average for one rotation, with 3436.29 yuan/ha invested during the planting phase and 2430.21 during the tending phase. Specifically, labor and cash expenses are 2376.20 yuan/ha and 1060.10 yuan/ha, respectively, during the planting phase; and they are 1691.04 yuan/ha and 739.17 yuan/ha, respectively, during the tending phase.

Of the policy variables, the proportion of plots taken for

Table 1
Descriptive statistics of selected variables.

Variable	Variable type	Mean	Standard deviation
Dependent variables			
Total investment (yuan/ha)	Continuous	5866.47	6192.88
Labor costs in planting phase (yuan/ha)	Continuous	2376.20	2507.71
Cash expenses in planting phase (yuan/ha)	Continuous	1060.09	1253.86
Total investment in planting phase (yuan/ha)	Continuous	3436.29	3761.73
Labor costs in tending phase (yuan/ha)	Continuous	1691.04	1819.99
Cash expenses in tending phase (yuan/ha)	Continuous	739.17	837.49
Total investment in tending phase (yuan/ha)	Continuous	2430.21	2567.23
Policy variables			
Forest type in plot (taken for environmental purpose = 1)	Categorical	0.25	0.24
Forest plot has a forest certificate (if yes = 1)	Categorical	0.68	0.46
Socio-Economic Variables			
Age of household head (years)	Continuous	56.07	9.10
Education of household head (years)	Continuous	7.83	3.31
Health condition of household head (if sick = 1)	Categorical	0.16	0.37
Number of household members with off-farm employment	Continuous	1.15	1.27
Credit constraint (if no constraints = 1) ¹	Categorical	0.85	0.35
Forest plot variables			
Area (ha)	Continuous	1.23	1.42
Slope (if steep = 1)	Categorical	0.37	0.48
Soil quality (if poor = 1)	Categorical	0.21	0.41
Age of stand (if young or middle aged = 1) ²	Categorical	0.61	0.48
Distance to home (km)	Continuous	2.65	3.42
Distance to road (km)	Continuous	2.12	2.10
Total number of plots	Continuous	4.47	2.01

Credit constraint was measured by asking the respondents whether they were able to successfully borrow money within one week (if yes = 1). Stands aged less than 15 years were classified as young or middle aged ones.

environmental purposes account for 25.5%, in which case the government restricts their commercial harvesting and provides a subsidy of 1200 yuan per ha per year in return, a figure which is far below adequate compensation for households' losses. Nearly 68% of the plots have a forest certificate, which not only demarcates the boundary of forestland but also guarantees the security of use rights.

In terms of socio-economic variables, the average age and education of household heads are 56 years and 7.8 years, respectively. Approximately 17% of household heads have diseases (chronic or severe), and the average number of migrant workers in a family is 1.16, indicating that almost a quarter of family laborers are migrant workers. About 85% of households faced credit constraints.

Regarding the forestland variables, the average forest plot area is 1.2 ha, while the average number of forest plots per household is 4.5, of which 16.7% of the households' plots number exceeds 5, indicating that there is a high degree of parcelization of forestland after the collective forest tenure reform. Nearly 38% of the forest plots are steep, more than 21% of the forest plots have poor soil quality, and more than 61% of the forest plots are young or middle-aged forests. The average distances of the forest plots to road and home are 2.1 km and 2.7 km, respectively.

5. Results and discussion

In this section, we first present the estimated parameters to reflect household risk preferences and then report and discuss our empirical results of the impacts of the household risk preferences on investment decisions. Finally, we briefly depict the outcomes of our robustness checking.

5.1. Risk preference parameters

It can be observed from Fig. 1 that in Series 1 and Series 2, 16% and 31% of respondents chose option B from the beginning to the end, which presented extreme risk-seeking, while 30% and 26% of respondents always chose option A, respectively, indicating that they were extremely risk-averse. The respondents who always chose option A and option B in all three series questions account for about 8% and 4%. Previous studies found similar results. Liu (2013), for example, reported that 7.6% of their subjects never showed the switching points in the experiment.

The frequency (namely the number of respondents) distribution of the three parameters is shown in Fig. 2a), b), and c). The respondents whose risk aversion parameter $\sigma > 0$ accounts for 79% (the mean of $\sigma = 0.36$), indicating that most respondents are risk-averse. The mean of probability weighting parameter α is > 1 ($\alpha = 0.77$), which suggests that the respondents overweight the small probabilities or underweight the high probabilities. The mean of the loss aversion parameter λ is 4.1, which is higher than the loss aversion coefficient $\lambda \approx 2$ of developing countries (Novemsky and Kahneman 2005), indicating that most respondents in our study area are more sensitive to the loss.

Other research on this topic has found similar results. Tanaka et al. (2010) tested the household risk preference in Vietnam, and the experimental results of σ , α , λ were 0.40, 0.75, 3.40, respectively. Liu (2013) and Karen (2011) carried out the same experiment in China, and the results of σ , α , λ were 0.48, 0.69, 3.47 and 0.42, 0.73, 6.02, respectively.

Fig. 1. Percentage distribution of switching points in a) series 1; b) series 2; and c) series 3 of the lottery experiment. Note: The numbers above the bars are the frequency of the respondents (303 in total) at different switching points.

Fig. 2. Frequency distribution of a) risk aversion parameter σ ; b) loss aversion parameter λ ; and c) probability weighting parameter α .

Table 2

Regression of risk preference variables on total forest investment.

Dependent variable: Total investment (log)	OLS	Tobit	Double-hurdle	
			Participation	Intensity
Risk preference variables				
Risk aversion parameter (σ)	-0.413*** (0.099)	-0.477*** (0.127)	-0.430** (0.227)	-0.219*** (0.034)
Loss aversion parameter (λ)	-0.012 (0.009)	-0.018 (0.012)	0.008 (0.014)	-0.021*** (0.005)
Probability weighting parameter (α)	0.035 (0.130)	0.099 (0.168)	0.069 (0.225)	-0.112* (0.069)
Policy variables				
Forest type in plot (taken for environmental purpose = 1)	-3.997*** (0.116)	-5.108*** (0.161)	-2.324*** (0.160)	-0.913*** (0.115)
Forest plot has a forest certificate (if yes = 1)	0.047 (0.087)	0.062 (0.112)	0.031 (0.141)	0.059** (0.034)
Socio-economic variables				
Age of household head (years)	0.005 (0.005)	0.005 (0.006)	0.006 (0.008)	0.004*** (0.002)
Education of household head (years)	-0.026* (0.014)	-0.040** (0.018)	-0.024 (0.031)	-0.003 (0.006)
Health condition of household head (if sick = 1)	-0.134 (0.115)	-0.211 (0.151)	-0.182 (0.182)	-0.075* (0.054)
Number of household members with off-farm employment	-0.222*** (0.035)	-0.298*** (0.046)	-0.263*** (0.064)	-0.015 (0.020)
Credit constraints (if no constraints = 1)	0.281** (0.120)	0.348** (0.157)	0.254 (0.201)	0.062 (0.052)
Forest plot variables				
Area (ha)	0.001 (0.002)	0.001 (0.002)	-0.003 (0.004)	0.003*** (0.001)
Slope (if steep = 1)	-0.105 (0.090)	-0.131 (0.116)	0.013 (0.133)	-0.098*** (0.035)
Soil quality (if poor = 1)	0.081 (0.108)	0.206 (0.141)	-0.411*** (0.162)	-0.356*** (0.040)
Age of stand (if young or middle aged = 1)	1.413*** (0.104)	1.550*** (0.132)	1.138*** (0.125)	0.688*** (0.074)
Distance to home (km)	-0.052** (0.020)	-0.096*** (0.028)	-0.107*** (0.032)	0.014** (0.008)
Distance to road (km)	-0.053*** (0.012)	-0.069*** (0.017)	-0.057*** (0.021)	-0.004 (0.006)
Total number of plots	-0.042* (0.022)	-0.053* (0.028)	-0.054 (0.043)	-0.011 (0.014)
Constant	5.843*** (0.410)	5.993*** (0.525)	2.102*** (0.657)	6.123*** (0.173)
F/ χ^2	210.35***	1748.23***	1496.85***	
Log likelihood	-	-2292.21	-919.79	

Note: 1. Standard errors in parentheses; *, **, and *** indicate significance at 10%, 5%, and 1% level, respectively.

2. The total number of observations in empirical model is 1352.

3. Village dummies were included to control for unobserved location-specific factors.

5.2. Impacts on investment intensity

Table 2 presents the marginal effects of the double-hurdle model with the bootstrap estimation procedure to correct heteroscedasticity. Standard errors were clustered at the household level to cope with the error term correlation, and village dummies were included to control for unobserved location-specific factors. The χ^2 statistic suggests that the model is well fit.

For comparison, we also reported the outcomes of the OLS and Tobit models. There are slight differences in the signs and significance levels of the coefficients, compared to OLS and Tobit models. The results of the double-hurdle model indicate that the household risk aversion parameter (σ) has a significant negative impact on the decision to invest and the intensity of timber forestry investment (-0.430 and -0.219, respectively, $P < 0.05$). The loss aversion parameter (λ) and probability weighting parameter (α) both have significant negative impacts on household investment intensity (-0.021 and -0.112, $P < 0.01$ and 0.10, respectively).

Overall, we can conclude that the more risk-averse households are, the lower their willingness to invest in timber forestry activities, and the lower their timber forestry investment intensities are. Hence, household forestry decisions might not aim to realize the maximization of the benefits as a rational-economic person, but to seek the maximization of “safety,” namely loss minimization. Considering the asset insecurity and opportunity costs, risk-averse households tend to have evasive attitudes towards forestry activities (Young 1979). In line with our expectations, households that own more plots designated for environmental purposes tend to invest less due to the harvesting constraints (Zhang and Wen 2008). Forest plots with a certificate have a significant positive impact on timber production investment, indicating that contracted property rights can stimulate investment.

Of the socio-economic variables, ‘Age of household head’ has a significant positive impact on forest investment intensity at the plot level ($P < 0.01$). This is inconsistent with the result of Yi et al. (2013), who demonstrated that the older the household head, the lower the investment intensity. The reason may be that older household heads are more inclined to engage in traditional on-farm work compared with younger people, due to less education, and more difficulty in obtaining off-farm employment opportunities. Health conditions of household heads also significantly impact investment intensity. Compared with other households, those whose heads are sick invest 7.5% less on their timber forestlands ($P < 0.10$). The effects of education of household heads on investment are insignificant, but more educated household heads are more likely to invest less, a finding also reported by Xie et al. (2013) and Yi et al. (2013).

Consistent with most empirical works (Xie et al. 2014; Xie et al. 2019), the more family members with off-farm employment in a household, the lower the probability of timber production investment is. Laborers tend to be assigned to more productive income sources, and households that engage in a large amount of off-farm work are faced with high opportunity costs of forest resource extraction and thus may be less likely to engage in timber production (Duan et al. 2016, 2017).

Some scholars argue that rural emigrants often sent remittances back to their families, thereby lessening production and investment constraints (Turner 1999; Wouterse and Taylor 2008). However, due to the lower present value of future returns and potential risks involved in timber production, the remittance effect from off-farm work was more difficult to be realized in forestry (Zhu et al. 2019).

Regarding the land variables, plot size has a significant positive impact on timber production investment ($P < 0.01$). Sloping, poor-quality forestland, and distance of forestland from home and road have significant negative effect. Unsurprisingly, slope and soil quality, as well as the location of forestland, determine the cost of forest management; therefore, the higher the cost of forest management, the more reluctant households are to invest in their timber production. Forest age significantly affects investment, whereby households would not invest, or invest less, in near-mature or mature forests. Forest parcelization (calculated as the total number of plots) has no significant impact on investment, although the negative coefficients indicate that forestland parcelization is not conducive to farmers' forestry input use (Xie et al. 2014; Liu et al. 2017).

5.3. Impacts on different investments

We further analyzed the impact of households' risk preferences on investments in different management stages, and the results are shown in Table 3. The household risk aversion parameter (σ) and probability weighting parameter (α) have significant negative impacts on both cash and labor costs in both planting and tending stages. Especially, the impact of the risk aversion parameter (σ) on cash spending is much larger than labor cost in both phases, showing that the risk-averse households are more reluctant to expend cash than labor. Interestingly, the coefficient loss aversion parameter (λ) has no significant effect on investment at the planting stage, but it has a significantly negative impact on investment at the tending stage ($P < 0.01$). A possible reason is that regardless of risk attitude, it is more essential for investing in establishing the stand than treating it later, and the specificity of forestry is such that a stand of trees will grow naturally after planting, even if there is little investment during the tending stage.

5.4. Robustness check

Our robustness check was done from multiple perspectives. First, we excluded those households who never had a switching point, and we re-ran our empirical model to avoid the estimation bias. Given that about 12% of the respondents never had switching points in the experiment, it may be argued that those subjects had not understood the requirements of the experiment. For simplicity, we only reported the results of the

intensity stage in the double-hurdle model. Second, given our assumption that the household head is predominate in family decision-making and the fact that not all the respondents were household heads, we surmise that the risk preferences of non-household heads may have little impact on their family forestry decisions. Therefore, we excluded the households whose respondents were not household heads.

Third, considering that some plots were planted before the tenure reform and had not been harvested yet, forest owners might not invest in these plots. So, we excluded all forest plots that were near mature or mature forest and re-ran the model. Fourth, considering that the forest investments of a household in different forest plots might be independent of each other, we replaced our initial estimation strategy with a random-effects Tobit model. By allowing for the correlation between error terms, the model can relax the assumption that the investment decision for each plot is made independently (Wooldridge 2002). We also re-estimated our empirical model at the household level through the Tobit model, rather than the plot level, to overcome the issue of error term correlation of each plots in each household. Meanwhile, we also reported the results of the initial model.

The results of all these five models show that the risk preference parameters have significant negative impacts on forestry investment intensity, indicating that the results obtained in this study are robust (Table D-1 of Appendix D).

6. Conclusions and policy implications

Using a combination of field experiment and econometric assessment, this study has generated a rich set of empirical findings. Overall, our results indicate that the more risk-averse rural households are, the lower their willingness to invest in timber forestry activities, and the lower their forestry investment intensity is. Risk-averse households are especially more reluctant to spend cash on forestry. Furthermore, the loss-averse households are more inclined to invest less in their forestlands during the tending phase than the planting phase. We hope that these findings have contributed to a better understanding of the relationship between household risk preferences and timber production investment.

This study has important implications to the formulation and implementation of policies that could enhance household timber production management. Risk in forest production causes inefficient input allocation. Households may not invest in forestry after the tenure reforms as much as policymakers and scientists would expect. Although many scholars have explored the causes for the lower-than-expected forestry investment, the results are not entirely satisfactory. Our study confirms that the household risk preferences greatly affect the willingness and intensity of timber forest investment. Due to the high-risk

Table 3
Regression of risk preference variables on forest investments at different phases.

Dependent variable: Cash and labor costs (log-transformed)	Planting phase			Tending phase		
	Cash expenses	Labor costs	Total investment	Cash expenses	Labor costs	Total investment
Risk preference variables						
Risk aversion parameter (σ)	-0.593*** (0.053)	-0.104*** (0.031)	-0.238*** (0.032)	-0.177*** (0.070)	-0.119*** (0.044)	-0.181*** (0.048)
Loss aversion parameter (λ)	-0.005 (0.007)	-0.002 (0.003)	-0.003 (0.003)	-0.022*** (0.006)	-0.027*** (0.006)	-0.031*** (0.006)
Probability weighting parameter (α)	-0.229** (0.101)	-0.280*** (0.064)	-0.269*** (0.067)	-0.261** (0.113)	-0.148*** (0.063)	-0.035 (0.076)
Policy variables	Yes	Yes	Yes	Yes	Yes	Yes
Socio-economic variables	Yes	Yes	Yes	Yes	Yes	Yes
Forest plot variables	Yes	Yes	Yes	Yes	Yes	Yes
χ^2	816.10***	1076.78***	1182.96***	786.65***	783.88***	1006.08***
Log likelihood	-1172.52	-682.38	-700.45	-1220.24	-1173.15	-1158.28

Note: 1. Standard errors in parentheses, and *, **, and *** indicate significance at 10%, 5%, and 1% level, respectively.

2. We only report the intensity results of the Double-hurdle model. Results of control variables are not reported here.

3. The total number of observations in empirical model is 1352.

4. Village dummies were included to control for unobserved location-specific factors

nature of timber production, the behavioral decision of households, in reality, is not completely 'rational' (in the economic sense). The decision-making standards of risk-averse households are more inclined to minimize losses rather than maximize profits, leading to lower-than-expected forestry investment. This outcome restricts the growth of China's forestry production. Although the collective forest tenure reforms have mitigated the tenure risk to a certain extent through property rights protection, the corresponding risk prevention mechanism has not yet been formed. Households are still concerned about the risks of forest management, such as policy instability.

Many scholars pointed out that changes in resource management policies might bring about unintentional or adverse outcomes (Galik and Jagger 2015; Ho 2018). In fact, the ownership of collective forests in China has changed frequently over time, leading to boundary disputes and a lack of security and stability of forest ownership. For example, in the 1980s, a large part of the collective forestland was distributed to the local households for management, but villages often quickly reversed the course once the reform ended. With this experience in mind, farmers are slow to believe that the reform is different this time (Qin and Xu 2013). To some extent this is one of the reasons why many forest owners did not invest, or invested less, and preferred to obtain a stable income from other sources, rather than the uncertain benefits from forestry. Safe and stable policy environments are the fundamental premise for households' long-term timber forestry investment. From a policy-maker's point of view, to improve farmers' enthusiasm and interest in timber production, attempts to encourage forest investment should be coupled with secure property rights and stable policy to mitigate the risk and fear of loss associated with forest investment.

The findings of this research are significant for three reasons. First, several possible hypotheses about lower-than-expected private forest investment of collective forest in China have been suggested, but few tackled risk preferences. The insights regarding the causes for the lower-than-expected individual investments in collective timber forestland after the tenure reform have seldom been addressed in association with household risk preference, which is an important factor to take into consideration when carrying out policy appraisal analysis in China and

elsewhere. Second, this study bridges the gap between field experiments and real-world behavior. The findings from this study suggest that lottery experiment results can predict the real-world decisions in the case of Chinese forest owners. This study strengthens the validity of field experiments. Third and finally, the evidence presented in this study from Fujian is relevant throughout China, and could have implications for other countries considering forest tenure reform through decentralization (Yin 2016). We anticipate that secure property rights and stable policy to hedge against the risk and fear of loss would be important considerations when establishing effective decentralized forest management elsewhere in the world.

This study has some limitations that need further attention. First, although we examined the robustness of our results in multiple ways, the potential endogeneity has not been considered. There might, therefore, be some unobservable factors linked to individual traits that may both influence risk preference and investment decision. The instrument variable approach should be a good way to alleviate this problem. In addition, this study was based on a cross-sectional dataset. However, given that forest production is a long-term dynamic process, panel data over the long-term should be used to take into account the dynamics of forest production.

Declaration of Competing Interest

The authors declare that there are no conflicts of interests regarding the publication of this article.

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Appendix A. Description of the lottery selection experiment

A.1. General Instructions for Respondents

All interviewed farmers were invited to participate in the lottery experiment. The goal of the lottery experiment was to elicit farmers' preference towards risk. Detailed instructions of the experiment were presented in the paper. Experimenters explained the tasks, rules, and procedures of the experiment to the participating farmers at the beginning. They were asked to listen carefully, with no chatting or discussion allowed during the experiment to ensure the effectiveness of the result. There were opportunities for the farmers to ask questions to ensure that all respondents understood how to perform the tasks. Cash payments were made at the end of the experiment. Respondents could then leave the room after receiving the payment. The respondents were asked to answer honestly and carefully.

A.2. Field Experiment Design and Procedures

Respondents were required to answer three independent series of questions that contained a total of 35 pair-wise lottery choices (14 questions each in Series 1 and Series 2, and 7 questions in Series 3). Each question had a choice between two binary lotteries, A or B. Respondents needed to make choices between A and B according to their personal preferences. The choices were carefully designed based on prospect theory, so that any combination of three series result could present three prospect theory parameter values. Series 1 and Series 2 were used to test the risk aversion coefficient σ and the probability weighting parameter α of the respondents. Series 3 was used to test the loss aversion coefficient λ .

The range of real-money payoffs was between a loss of 20 yuan and a gain of 850 yuan, which was determined by two parts. One was certain payment. Everyone who completed the task will receive 20 Yuan. Extra payment was given depending on the respondents' decisions and luck in lottery selections. When respondents completed all three series of questions, one question was chosen randomly for the final reward of the experiment, which was decided between the high and low payoff of the questions by flipping a coin. In Series 1 and Series 2, the respondents always received positive payoffs regardless of whether they selected Option A or B, whereas the payoff amount was different between the different options. However, in Series 3, the options could result in negative payoffs.

Table 6 is the first line of Series 1. Option A indicates that there was a 30% probability of getting 20 yuan, and a 70% probability of getting 5 yuan. Option B indicates that there was a 10% probability of getting 34 yuan, and a 90% probability of getting 2.5 yuan. In Series 1 and Series 2, the utility value of Option B (= payoff $\times$ probability) gradually increased and was eventually higher than that of Option A. Respondents had to decide whether

they preferred option A versus Option B for each line. In Series 1, if the switching point appeared earlier, it meant that the respondent over weighted the high-payoff event with the probability of 10% (Option B).

Table A-1
Example of risk preference experiment choice.

A	B
20 Yuan:●●●●	34 Yuan:●
5 Yuan:○○○○○○	2.5 Yuan:○○○○○○○○

In Series 1, Option A was fixed but the expected value of Option B increased and eventually exceeded that of Option A. In Series 2, the questions were similar to those of Series 1, but with different payoffs and probabilities. If responders stayed longer in Option A in both Series 1 and Series 2, this indicated more risk aversion. Since the preference reversal was beyond the scope of this study, monotonic switching was enforced in each series to eliminate the possibility of inconsistent choices. Once a respondent switched to Option B they were not allowed to switch back to Option A. Therefore, there was only one switch point in each series to be identified. The “switching point” was the “decision reference point” in the prospect theory. It was possible that a respondent always selected Option A or option B in the series, which meant the respondent had extreme risk-averse or risk-seeking preferences. For example, if a respondent never switched from Option A to B in Series 1 or Series 2, the individual was considered extremely risk averse. Conversely, if a respondent chose Option B from the beginning of Series 1 and Series 2, the individual was considered to have the strongest risk-seeking preference.

The switching point in Series 3 determined the loss aversion parameter λ . Respondents' options in Series 3 might result in a negative payoff, which would not exceed the amount of 20 yuan. The negative payoff would be deducted from the certain payment, which was 20 yuan, since it was unethical to let respondents suffer a loss in the experiment. Notice that λ could not be uniquely inferred from switching in Series 3; the range of λ values that was implied by each switching point depends on the utility curvature σ . However, questions in Series 3 were constructed to make sure that λ took similar values across the difference level of σ . The later that responders switched from A to B, the more averse they were to losses. For example, if a respondent switched from Option A to option B at the 7th question in Series 1, the 7th question in Series 2, and the 5th question in Series 3, the following inequalities should hold:

$$5^{(1-\sigma)} + \exp[-(-\ln.3)^{\alpha}](20^{(1-\sigma)} - 5^{(1-\sigma)}) > 2.5^{(1-\sigma)} + \exp[-(-\ln.1)^{\alpha}](62.5^{(1-\sigma)} - 2.5^{(1-\sigma)})$$

$$5^{(1-\sigma)} + \exp[-(-\ln.3)^{\alpha}](20^{(1-\sigma)} - 5^{(1-\sigma)}) < 2.5^{(1-\sigma)} + \exp[-(-\ln.1)^{\alpha}](75^{(1-\sigma)} - 2.5^{(1-\sigma)})$$

$$15^{(1-\sigma)} + \exp[-(-\ln.9)^{\alpha}](20^{(1-\sigma)} - 15^{(1-\sigma)}) > 2.5^{(1-\sigma)} + \exp[-(-\ln.7)^{\alpha}](32.5^{(1-\sigma)} - 2.5^{(1-\sigma)})$$

$$15^{(1-\sigma)} + \exp[-(-\ln.9)^{\alpha}](20^{(1-\sigma)} - 15^{(1-\sigma)}) < 2.5^{(1-\sigma)} + \exp[-(-\ln.7)^{\alpha}](34^{(1-\sigma)} - 2.5^{(1-\sigma)})$$

The ranges of σ and α that satisfied the above inequalities were $0.26 < \sigma < 0.35$ and $0.66 < \alpha < 0.74$. The approximate mid-point was $(\sigma, \alpha) = (0.3, 0.7)$. Mid-points were taken for the parameters as explanatory variables in the regression model. When respondents did not switch, the approximate values at the boundaries were used. With the values of σ and α , a set of inequalities could be constructed from the switch point in Series 3, and then get the upper and lower bound of λ . Mid-points were also taken to estimate the values of λ in regression models.

Appendix B. Record Sheet of Risk Preference

Series1	
A	B
20 Yuan:●●●●	34 Yuan:●
5 Yuan:○○○○○○	2.5 Yuan:○○○○○○○○
20 Yuan:●●●●	37.5 Yuan:●
5 Yuan:○○○○○○	2.5 Yuan:○○○○○○○○
20 Yuan:●●●●	41.5 Yuan:●
5 Yuan:○○○○○○	2.5 Yuan:○○○○○○○○
20 Yuan:●●●●	46.5 Yuan:●
5 Yuan:○○○○○○	2.5 Yuan:○○○○○○○○
20 Yuan:●●●●	53 Yuan:●
5 Yuan:○○○○○○	2.5 Yuan:○○○○○○○○
20 Yuan:●●●●	62.5 Yuan:●
5 Yuan:○○○○○○	2.5 Yuan:○○○○○○○○
20 Yuan:●●●●	75 Yuan:●
5 Yuan:○○○○○○	2.5 Yuan:○○○○○○○○
20 Yuan:●●●●	92.5 Yuan:●
5 Yuan:○○○○○○	2.5 Yuan:○○○○○○○○
20 Yuan:●●●●	110 Yuan:●
5 Yuan:○○○○○○	2.5 Yuan:○○○○○○○○
20 Yuan:●●●●	150 Yuan:●
5 Yuan:○○○○○○	2.5 Yuan:○○○○○○○○
20 Yuan:●●●●	200 Yuan:●
5 Yuan:○○○○○○	2.5 Yuan:○○○○○○○○
20 Yuan:●●●●	300 Yuan:●
5 Yuan:○○○○○○	2.5 Yuan:○○○○○○○○
20 Yuan:●●●●	500 Yuan:●
5 Yuan:○○○○○○	2.5 Yuan:○○○○○○○○
20 Yuan:●●●●	850 Yuan:●
5 Yuan:○○○○○○	2.5 Yuan:○○○○○○○○

I chose lottery A for Line 1 to ____.

I chose lottery B for Line ____ to 14.

Series 2

A	B
20 Yuan:●●●●●●●●	27 Yuan:●●●●●●●●
15 Yuan:○	2.5 Yuan:○○○
20 Yuan:●●●●●●●●	28 Yuan:●●●●●●●●
15 Yuan:○	2.5 Yuan:○○○
20 Yuan:●●●●●●●●	29 Yuan:●●●●●●●●
15 Yuan:○	2.5 Yuan:○○○
20 Yuan:●●●●●●●●	30 Yuan:●●●●●●●●
15 Yuan:○	2.5 Yuan:○○○
20 Yuan:●●●●●●●●	31 Yuan:●●●●●●●●
15 Yuan:○	2.5 Yuan:○○○
20 Yuan:●●●●●●●●	32.5 Yuan:●●●●●●●●
15 Yuan:○	2.5 Yuan:○○○
20 Yuan:●●●●●●●●	34 Yuan:●●●●●●●●
15 Yuan:○	2.5 Yuan:○○○
20 Yuan:●●●●●●●●	36 Yuan:●●●●●●●●
15 Yuan:○	2.5 Yuan:○○○
20 Yuan:●●●●●●●●	38.5 Yuan:●●●●●●●●
15 Yuan:○	2.5 Yuan:○○○
20 Yuan:●●●●●●●●	41.5Yuan:●●●●●●●●
15 Yuan:○	2.5 Yuan:○○○
20 Yuan:●●●●●●●●	45 Yuan:●●●●●●●●
15 Yuan:○	2.5 Yuan:○○○
20 Yuan:●●●●●●●●	50 Yuan:●●●●●●●●
15 Yuan:○	2.5 Yuan:○○○
20 Yuan:●●●●●●●●	55 Yuan:●●●●●●●●
15 Yuan:○	2.5 Yuan:○○○
20 Yuan:●●●●●●●●	65Yuan:●●●●●●●●
15 Yuan:○	2.5 Yuan:○○○

I chose lottery A for Line 1 to ____.

I chose lottery B for Line ____ to 14.

A	B
12.5 Yuan:●●●●●	15 Yuan:●●●●●
-5Yuan:○○○○○	-10Yuan:○○○○○
2 Yuan:●●●●●	15 Yuan:●●●●●
-2Yuan:○○○○○	-10Yuan:○○○○○
0.5 Yuan:●●●●●	15 Yuan:●●●●●
-2Yuan:○○○○○	-10Yuan:○○○○○
0.5Yuan:●●●●●	15 Yuan:●●●●●
-2Yuan:○○○○○	-8Yuan:○○○○○
0.5 Yuan:●●●●●	15 Yuan:●●●●●
-4Yuan:○○○○○	-8Yuan:○○○○○
0.5Yuan:●●●●●	15 Yuan:●●●●●
-4Yuan:○○○○○	-7Yuan:○○○○○
0.5Yuan:●●●●●	15 Yuan:●●●●●
-4Yuan:○○○○○	-5Yuan:○○○○○

I chose lottery A for Line 1 to ____.

I chose lottery B for Line ____ to 7.

Appendix C. Household questionnaire (partial)

Personal information of family members

Codes of family members	Relationship with household head	Gender	Age	Ethnic group	Religion	Education②	Health condition	Village leadership	Rural migration③	Migration Time
	Q1	1 male 2 female	years	Q2	Q3	years	Q4	Q5	1Yes, 0No	months
H1	1 household head									
H2										
...										

Q1:1 household head 2 spouse 3 parents 4 children 5 grandchildren 6 others 9 respondent.

Q2:1 the Han nationality 2 the Qiang nationality 3 the Tibetan nationality 4 the Baima Tibetan nationality 5 the Yi nationality 6 others.

Q3:0 no belief 1 folk belief (worship Mazu, Guan Yu, etc.) 2 Buddhism 3 Tibetan Buddhism 4 Taoism 5 Christianity 6 Islam 7 Catholicism 8 others.

Q4:1 healthy 2 non-serious disease 3 chronic disease 4 serious illness 5 disability.

Q5:1 Now you are a village cadre; 2 You used to be a village cadre; 0 You are not a village cadre.

Note: A family is a group of people living under the same roof, sharing various resources (labor force and income), sharing the income and expending together.

②Years of study: 6 years in primary school, 9 years in junior high school, 12 years in senior high school, 16 years in university, 11 years in technical secondary school, 15 years in junior college, 19 years in post-graduate school.

③Rural migrants were defined as a family member who chose to work outside the county for more than three months in the survey year.

(continued)

Mental state			Instantaneous memory	Computing power					Delayed memory
Please tell me the date of today?	What week is it today?	Which season is it now?	The number of words remembered ②	How much is 100 minus 7?	Go on minus 7	Go on minus 7	Go on minus 7	Go on minus 7	The number of words remembered ②
correct									
3 day is correct									
4 no correct									

Note:

Respondents do not have to answer in order. If the respondent is an elderly person and answers according to the lunar calendar, and if the date corresponding to the calendar is accurate, then you can check its accuracy by calendar conversion;

Hint: We will read ten words to you. Please listen carefully. We will not repeat them. Please remember as many as possible. We intend to list so many words to increase the difficulty of remembering. After reading, you will be asked to recall these words, not in order. Do you understand? [Note: please don't let the agent answer. Respondents were asked to randomly select a group of words, and the investigators read them slowly, two seconds apart, so they could read the words. Tip: Please try to remember the words I just read to you, and I'll ask you to recall them later. [Note: After completing the computational test, about five minutes later, ask the respondent to continue recalling the words on the selected card].

Appendix D. Robustness Check Results

Table D-1

Impacts of Risk Preference Variables on Total Investment.

Dependent Variable: Total investment (log)	Drop NS ^a	Drop NH ^b	Drop MF ^c	RE Tobit ^d	Household level ^e	Original ^f
Risk preference variables						
Risk aversion parameter (σ)	-0.193** (0.083)	-0.279*** (0.036)	-0.247*** (0.082)	-0.470*** (0.139)	-0.381*** (0.113)	-0.219*** (0.034)
Loss aversion parameter (λ)	-0.020*** (0.010)	-0.016*** (0.004)	-0.018** (0.008)	-0.017 (0.013)	-0.018* (0.010)	-0.021*** (0.005)
Probability weighting parameter (α)	-0.134* (0.064)	-0.103* (0.064)	-0.124 (0.112)	0.105 (0.181)	0.023 (0.140)	-0.112* (0.069)
Socio-economic variables	Yes	Yes	Yes	Yes	Yes	Yes
Forest plot variables	Yes	Yes	Yes	Yes	Yes	Yes
Policy variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1035	1207	826	1352	303	1352
Chi2	1392.45***	1788.32***	1285.35***	2396.36***	454.80***	1496.85***
Log likelihood	-1731.34	-955.56	-1452.30	-2290.16	-345.27	-919.79

Note: 1. Standard errors in parentheses, and *, **, and *** indicate significance levels of 10%, 5%, and 1%, respectively.

2. Estimated results of control variables are not reported here.

3. Village dummies were included to control for unobserved location-specific factors.

4. Alternative perspectives and treatments.

^a Excluding all individuals who chose only A or only B in all 3 series.

^b Excluding all interviewed individuals who are not household head.

^c Excluding all forest plots if they are near mature or mature forest.

^d Random-effects Tobit model was used, which allows for the correlation between error terms.

^e Tobit model at household level, rather than plot level.

^f Original results are from Column 6 of Table 2.

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