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Risk preference, farm diversification and crop selection: Evidence from China

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Selected Paper prepared for presentation at the 2021 Agricultural & Applied Economics Association Annual Meeting, Austin, TX, August 1 – August 3

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Risk Preference, Farm Diversification and Crop Selection: Evidence from China

Licheng Xu *

May 20, 2021

Abstract

This study examines the influence of risk preference on crop selection, and how it further affects the decision of farm diversification. I first develop an analytical framework with three crop choices to investigate the rationale behind the the decision of farm diversification versus specialization. The model predicts that farmers' preference for a certain crop type has a nontrivial correlation with the decision of farm diversification under different risk preferences. Using nationally representative data from three waves of the China Household Finance Survey (CHFS) between 2011 and 2015, I show that risk-averse households are on average 6.3 to 6.7 percent less likely to adopt farm diversification than risk-neutral and risk-loving households. A further exploration of the crop choice shows that risk-averse households, especially those with extreme risk aversion, have a strong preference for food crops over all other crops and farm products, which is possibly driven by the motive of ensuring food self-sufficiency and a lower price volatility. Based on the theoretical and empirical findings, I conclude that crop selection is a well-utilized risk-coping strategy that gains more popularity than farm diversification among the risk-averse households in rural China and possibly other parts of the developing world.

Keywords: risk preference; farm diversification; crop selection; household; China

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1 Introduction

Farm production is susceptible to a variety of risk and uncertainty arising from natural disasters, price fluctuation, institution or policy regulation, and many other related aspects.[1] In developed countries, the insurance market and agricultural income support programs provide useful tools of risk management for farmers (Hennessy, 1998). In less developed regions, however, due to a lack of well-developed insurance market, farmers have to find alternative ways to manage risks. In addition to contract farming and precautionary savings (Fafchamps, 2010), farm diversification is a widely adopted risk-coping strategy among smallholder farmers of the developing world (Benin et al., 2004; McCord et al., 2015; Lawin and Tamini, 2017).

Farm diversification is the practice of cultivating two or more crops at the same time on a given farm.[2] In addition to the frequently studied motive of risk management, several other rationales are explored in the literature. For example, farm diversification may be driven by the presence of economies of scale. Diversification leads to scope economies when there is a cost reduction during the multi-output production process (Chavas and Holt, 1996; Chavas and Di Falco, 2012). Additionally, time preferences and crop types can also affect the decision of farm diversification (Sarwosri and Mußhoff, 2020).

The aim of this study is twofold. The first objective is to investigate whether and how risk preference affects the decision of farm diversification for rural households. To establish this causal linkage, I first develop a stylized theoretical model to analyze the household decision of farm diversification and crop selection under uncertainty. Then, I use nationally representative household survey data from China to test the hypothesis from the theoretical framework. Additionally, I explore whether risk preference affects the specific type of crops that rural households cultivate on their farms. This analysis provides a useful complement to the analysis on farm diversification, which may be affected by the choice of certain crops on the farm.

There is an extensive body of literature on the impact of risk and risk attitudes on farm management (Chavas et al., 2010), including but not limited to technology adoption (Liu, 2013; Barham et al., 2014), input use (Liu and Huang, 2013), and labor allocation (Hill, 2009). Related work explores the causal connection between risk attitudes and

[1] For a more detailed discussion, see the article "Risk in Agriculture" from United States Department of Agriculture, Economic Research Service (https://www.ers.usda.gov/topics/farm-practices-management/risk-management/risk-in-agriculture).

[2] Some studies use the term "crop diversification" as an alternative to "farm diversification". Despite the potential subtle difference, I do not differentiate between the two terms in this study.

migration decisions, which generally finds that migration is usually associated with a risk loving preference, and vice versa (Jaeger et al., 2010; Akgüç et al., 2016; Dustmann et al., 2020). In contrast, there is a relatively smaller strand of literature on farm diversification, for which the empirical findings are contradictory. Some studies find that farmers' risk aversion may impose a negative and significant impact on farm diversification (Hellerstein et al., 2013; Lawin and Tamini, 2017). On the contrary, other related work finds that risk aversion encourages the practice of farm diversification (Bezabih and Sarr, 2012; Chavas and Di Falco, 2012), which is consistent with the common perception in the literature that characterizes farm diversification as a risk-coping strategy. One crucial reason for the contradictory findings is the failure to control for the specific crop choices, which may be an important confounding factor affecting the decision of specialization versus diversification. Another possible cause for this controversy is the accuracy or reliability of the measure for risk attitudes. Lottery choices are frequently transformed into a measure of risk attitude, but it "may not reflect the deep-seated risk aversion" (Hellerstein et al., 2013). In this study, I avoid the measure derived from specific pay-offs of different lottery choices. Instead, I follow Hill (2009) and use the stated risk preference as the key explanatory variable for rural households' decision of farm diversification. Besides, I take into account the possibility that households with strong risk aversion may have a preference for crops that are normally considered less risky. This could potentially affect rural households' decision of farm diversification.

This study contributes to the literature in the following ways. First, the analytical framework developed in this study is a useful tool to examine how risk preference affects the decision of farm diversification as a risk-coping strategy for farmers in the developing world. Second, this study not only analyzes crop diversification in general, but also discusses farm households' potential preference for certain crop types under the influence of risk attitudes. This is rarely discussed in the literature, with exceptions like Sarwosri and Mußhoff (2020). Third, to the best of our knowledge, existing studies that provide empirical evidence for farmers' risk attitudes and the decisions of farm diversification and crop selection in China are scarce. Empirical results presented in this study can be utilized for cross-country comparisons as well.

The remainder of the paper proceeds as follows. Section 2 develops a theoretical framework that serves as an analytical tool to explore the potential connection between risk preference, farm diversification and crop selection. Section 3 describes the data used in this study and illustrates the identification strategies for empirical analysis. Then, Section 4 reports the empirical results and discusses the main findings. Finally, Section 5

concludes and provides some discussions based on my findings.

2 Theoretical Framework

In this section, I develop a stylized model to explore the representative household's decision-making progress on whether to adopt crop diversification and specific crop choices on its farm. Based on the setup for a representative decision-maker's expected utility under risk and uncertainty originally developed by Hennessy (1998), I introduce the potential price shocks and three planting options for the representative household to choose from: (a) food crops only, (b) cash crops only and (c) both food crops and cash crops. The theoretical framework presented in this study yields testable hypothesis for the rational choice between specialization and diversification, together with specific crop choices.

Consider a representative farm household with a land endowment of T. Assume that there is no market for land transfers. Labor and capital inputs for farm production are both normalized to 1. The household has three planting options: food crops only (A), cash crops only (B), or both food crops and cash crops (C). The production technology is $y_A = f(T)$ for food crops and $y_B = g(T)$ for cash crops, with $f'(T) > 0, f''(T) \leq 0$; and $g'(T) > 0, g''(T) \leq 0$. The average price of food crops is lower than cash crops, but the market price of cash crops are more volatile than food crops. Mathematically, the unit price of food crops and cash crops are 1 and p ($p > 1$), respectively. Assume that cash crops are subject to a wider range of price fluctuation than food crops. That is, when food crops are planted, the farm household faces a price shock of $\epsilon \in [-a, a]$ ($0 < a \leq 1$). In contrast, when cash crops are planted, the price shock is $\eta \in [-1, 1]$. For simplicity, assume that the price shock to either crop follows a uniform distribution. Without loss of generality, the fixed cost for planting either crop is assumed to be zero. Assume that there is no other risk other than price risk.

Under this setting, the revenue from planting food crops alone can be written as $R_A(T; \epsilon) = (1 - \epsilon) \cdot f(T)$. The return from planting cash crops alone can be written as $R_B(T; \eta) = p(1 - \eta) \cdot g(T)$. Alternatively, the household can choose to allocate the proportion δ of its total land endowment to cash crops, and the remaining share $(1-\delta)$ to food crops ($0 < \delta < 1$). The corresponding revenue is $R_C = R_A((1 - \delta)T; \epsilon) + R_B(\delta T; \eta)$.

Suppose the household's preference over revenue is characterized by $U(R) = \frac{1-e^{-\gamma R}}{\gamma}$. The sign of γ determines the risk preference of the household: $\gamma < 0$ indicates risk loving; $\gamma = 0$ suggests risk neutrality ($U(R) = R$); and $\gamma > 0$ denotes risk aversion. The

household's expected utility with the three planting options can be represented by:

$$\begin{aligned} EU_A &= EU[R_A(T;\epsilon)] = \int_{-a}^{a} U[R_A(T;\epsilon)]d\epsilon, \\ EU_B &= EU[R_B(T;\eta)] = \int_{-1}^{1} U[R_B(T;\eta)]d\eta, \\ EU_C &= EU[R_A((1-\delta)T;\epsilon) + R_B(\delta T;\eta)] \\ &= \int_{-a}^{a}\int_{-1}^{1} U[R_A((1-\delta)T;\epsilon) + R_B(\delta T;\eta)]d\eta d\epsilon, \end{aligned}$$

where EU_A, EU_B and EU_C denote the expected utility from three planting options: food crops only, cash crops only, and both food crops and cash crops. A rational decision-maker of the representative household would select one of the three planting options that generates the highest expected utility. It is likely that farm households with different risk preferences would make different planting arrangements.

A complete set of model predictions requires a rigorous case-by-case discussion, given the value range of all parameters and the functional form of production technologies. I illustrate the derivation process in Appendix B with one plausible set of parametric assumptions on the production technology of food and cash crops, as well as the functional form for three possible risk preferences. One key prediction from the model is that there is a nontrivial connection between crop choices and the decision on farm diversification versus specialization, which could potentially affect the impact of risk attitudes on the decision of farm diversification. Therefore, the main takeaway from the theoretical model is that the choice of specific crop types should not be neglected in examining the causal linkage between risk preference and the decision of farm diversification. In the empirical analysis to follow, I explore the interaction among risk preference, crop choice and farm diversification based on evidence from farm households in China.

3 Data and Empirical Methodology

3.1 Data Source and Summary Statistics

To empirically test our model predictions, I use data from the China Household Finance Survey (CHFS), a nationwide survey in China on household finance and assets. The survey includes both urban and rural household samples. For rural households, information on farm characteristics, including farm size, the acreage of all crops planted and corre-

sponding earnings, is also collected. Currently three waves of data (2011, 2013 and 2015) are publicly available. In the baseline wave in 2011, 8,438 households in 25 provinces and 80 counties were surveyed. In 2013, the survey covered 28,141 households in 29 provinces and 267 counties. In 2015, the provincial coverage does not change but the number of counties incorporated in the survey increased to 351.[3] And correspondingly, the sample size in 2015 increased to 37,289 households. In all three years, the household samples are representative at both national and province level. I first pool data from all three waves of survey into a panel dataset for empirical analysis. Then, I restrict my analysis to rural households only. Table 1 presents the summary statistics of the final sample for analysis.

The first observation regarding household characteristics is that the average family size is around 4, and roughly half of the household labor is allocated to farm production. In line with this, around 72 to 73 percent of the rural households surveyed reported that they are engaged in agricultural production. The average farming season is 7 months. It is clear that farm production is still an important source of income for rural households in China, which has been on the rise over the study period. Farm households are generally very cautious about farm diversification. The average categories of crops on the family farm is between 1.4 and 1.6. Additionally, over 70 percent of the surveyed households received government subsidies on agricultural production. But the percentage is on the decline over the period 2011-2015. Last but not least, seeking credit for farm production and starting business off farm is not common for the rural households surveyed, the share of which in the whole sample is around 10 percent or lower.

In terms of specific crop choices, I categorize all surveyed households into four types, as shown in Table 2. It is clear that "cash crops only" is the most risky option, and fewest households made this choice. In comparison, "food crops only" were the most popular option for the rural households surveyed, which comprise of 36.5% and 43.6% of all surveyed households. In 2015, however, most households turned to all other products. From these dynamics, we can see that in addition to the practice of farm diversification, the specific type of crop choices is also essential in understanding rural households' risk-coping strategies.

[3]There are in total 31 provinces in mainland China. In 2011, six provinces were not covered by CHFS, including Inner Mongolia, Fujian, Hainan, Ningxia, Xinjiang and Tibet. Among these six provinces, only Xinjiang and Tibet were not covered in 2013 and 2015.

3.2 Empirical Methodology

The goal of this study is to evaluate the potential impact of farmers' risk preference on the decision of farm diversification and specific crop choices. The main explanatory variable, risk preference, comes from the following question in the survey: *"Which of the choice below do you want to invest most if you have adequate money? (i) Project with high risk and high return; (ii) Project with slightly high risk and slightly high return; (iii) Project with average risk and return; (iv) Project with slight risk and return; (v) Unwilling to carry any risk."* I categorize options (i) and (ii) as "risk loving", option (iii) as "risk neutral", and options (iv) and (v) as "risk averse". As for the outcome, the most direct and intuitive way to measure farm diversification is simply counting the total types of crops planted by a certain household. Figure 1 presents a qualitative correlation between risk preference and farmers' decision of farm diversification. Risk-loving households on average cultivate slightly more types of crops than risk-neutral households. The average count of crop types on the farm of risk-averse households is, on the other hand, lower than risk-neutral households. Extremely risk averse households cultivate the least number of crops on average. To quantify the impact of risk preference on the decision of farm diversification, I estimate the following linear fixed-effects model:

$$CD_{it} = \theta_0 + \theta_1 RA_{it} + \theta_2 RL_{it} + X'_{it}\xi + \mu_i + \lambda_t + \varepsilon_{it}, \tag{1}$$

where CD_{it} is the crop diversification measure of farm household i in year t, which is either a binary indicator for diversification over two or more crops on the farm or the total types of crops that are cultivated; RA_{it} and RL_{it} are two dummies that indicate whether household i exhibits risk aversion or risk loving in year t, respectively (risk neutrality is treated as the base group); X_{it} is a vector of household socioeconomic variables, including the number of household laborers engaged in farming, duration of the last farming season, whether household received government subsidy on farming, whether household received bank loan for farming, and whether household started its own business off farm; μ_i is household fixed effect; λ_t is year fixed effect, ε_{it} denotes unobserved errors. The parameters of interest are θ_1 and θ_2. Alternatively, I also use the original five-point ratings for risk attitudes and get a set of results to check for robustness.

As a complement to the linear specification on farm diversification denoted by Equation (1), we perform a multinomial logit estimation with risk preference measures and the same set of household-level controls to explore the household's choice of crops. The

corresponding specification is denoted as:

$$Prob(Type_{it} = k) = F(\beta_{0,k} + \beta_{1,k} RA_{it} + \beta_{2,k} RL_{it} + X'_{it}\xi_k + \mu_i + \lambda_t), \quad k \in \{1, 2, 3, 4\} \tag{2}$$

$F(\cdot)$ is the cumulative distribution function (CDF) for the standard multinomial logit model; $Type_{it}$ is an indicator for the type of crops cultivated on the family farm of a specific household in a given year, which takes four possible values: 1=food crops, 2=cash crops, 3=combination of food crops and cash crops; and 4=all other products; μ_i is household random effect; λ_t is year random effect. All other variables are defined in the same way as in Equation (1). Similar to the analysis on farm diversification, I include the set of results using the original five-point ratings for risk preference to check for consistency. The corresponding results help identify whether there is a preference for food crops among risk-loving and risk-averse farm households.

4 Results

This section reports empirical results for the estimated effect of risk preference on farm diversification and specific crop choices. Corresponding results are presented in Table 3 through Table 5.

I begin by discussing the results for evaluating the causal connection between risk preference and farm diversification, based on the linear fixed-effects model shown in Equation (1) above. Two sets of results with two different measures for farm diversification are reported in Table 3 and Table 4, respectively. Starting with the binary indicator for farm diversification, roughly 51 percent of all households in the sample choose farm diversification. As shown in Panel A of Table 3, compared with risk-neutral households, the probability of adopting farm diversification is not significantly different in risk-loving households, while 3.2-3.4 percentage points (or 6.3 to 6.7 percent) lower in risk-averse households. With a more detailed categorization of risk preference as shown in Panel B of Table 3, the results suggest that the decline in the tendency of adopting farm diversification is mostly driven by the households with extreme risk aversion. The results are generally consistent when the binary indicator measure of farm diversification is replaced by the total number of crop types on the farm. As shown in Panel A of Table 4, the total number of crop types is not significantly different between risk-loving and risk-neutral households. In contrast, the total count of crop types on the farm of risk-averse households

is 0.05 to 0.06 lower than risk-neutral households. This impact is statistically significant, though relatively small in magnitude compared with the outcome mean (roughly 1.5). Panel B provides additional evidence that this decline in the total count of crop types is driven mostly by those extremely risk-averse households. For moderately risk-averse households, the average count of crop types on the farm is not significantly different from risk-loving and risk-neutral households. In summary, extreme risk aversion leads to a tendency to resist crop diversification. This result may be a little counter-intuitive, as farm diversification is normally considered as a risk-coping strategy in the literature.

To better understand the rationale behind the resistance of farm diversification among risk-averse households in China, I continue to explore whether these households have any preference for certain crop types, based on the multinomial logit model denoted by Equation (2) above in Section 3. I categorize all households into four types based on the crop choice, food crops only, cash crops only, food and cash crops and all other products (harvested from animal husbandry, forestry, and/or fishery businesses), and choose the option of food crops only as the base group. Corresponding results are presented in Table 5. My first finding is that the predicted probability for risk-loving households choosing either cash crops only, a combination of food and cash crops, or other farm products is not significantly different from them choosing food crops only. In other words, risk-loving households show no preference for any certain crop type. In contrast, the predicted probability of risk-averse households choosing food crops only is significantly higher than them choosing any of the other three options. This suggests that (extremely) risk-averse households have a special preference for food crops, possibly due to a smaller price volatility than other types of crops or farm products. A related explanation is the motive of food sufficiency. Unless hit by extreme natural disasters, planting food crops provides these risk-averse households with a kind of insurance against the risk of starvation. For either of the two reasons, the observed preference for food crops among risk-averse households. This result is also consistent with findings in the earlier literature that Third World farmers with a small farm scale devote a smaller share of their land to cash crops to manage risks and ensure food self-sufficiency (Fafchamps, 1992), as the farm scale for most rural households in China is also quite small (an average of 1-2 acres).

The main takeaway from the empirical results based on evidence from Chinese farm households is that farm diversification may not be the most favorable option to manage risks. For the extremely risk-averse farm households, they may seek for alternative methods for risk management, among which crop selection seems to be one popular choice. By choosing to grow food crops, they have a better control of the price volatility of their

farm products and enjoy more secured food self-sufficiency in the meantime.

5 Conclusion and Discussion

This study examines the potential causal linkage between farmers' risk preference and the decision of farm diversification and crop selection. I first develop a simple but informative analytical framework for analyzing farmers' rational choice about farm diversification and crop selection. The main takeaway from the theoretical model is that the choice of specific crop types should not be neglected in examining the causal linkage between risk preference and the decision of farm diversification. This theoretical prediction is echoed by my empirical findings. Using three waves of data from the CHFS between 2011 and 2015, I have two major findings. First, I find that risk-averse households are on average 6.3 to 6.7 percent less likely in the adoption of farm diversification compared with the risk-neutral and risk-loving counterparts. The lower tendency to adopt farm diversification is mostly driven by the extremely risk-averse households. This finding is consistent with some studies in the literature (Hellerstein et al., 2013; Lawin and Tamini, 2017) but also contradict with some others (Bezabih and Sarr, 2012; Chavas and Di Falco, 2012). Second, risk preference affects crop selction. Risk-loving households show no preference in the choice of crop types. In comparison, risk-averse households (especially extremely risk-averse households) tend to have a preference for food crops compared with all other crops or farm products. This is potentially driven by the desire of food self-sufficiency and a lower price volatility to ensure a relatively stable farm income.

Taken together, evidence presented in this study suggests that we may fail to accurately grasp the rationale behind rural households' farming decisions if we focus too narrowly on the discussion of farm specialization versus diversification. Instead, we probably need to take into account alternative risk-coping strategies other than farm diversification. In China and possibly other parts of the developing world, extreme farm households may stick to certain crop types (for example, food crops) as a more direct way than farm diversification in managing economic risks and ensuring food self-sufficiency.

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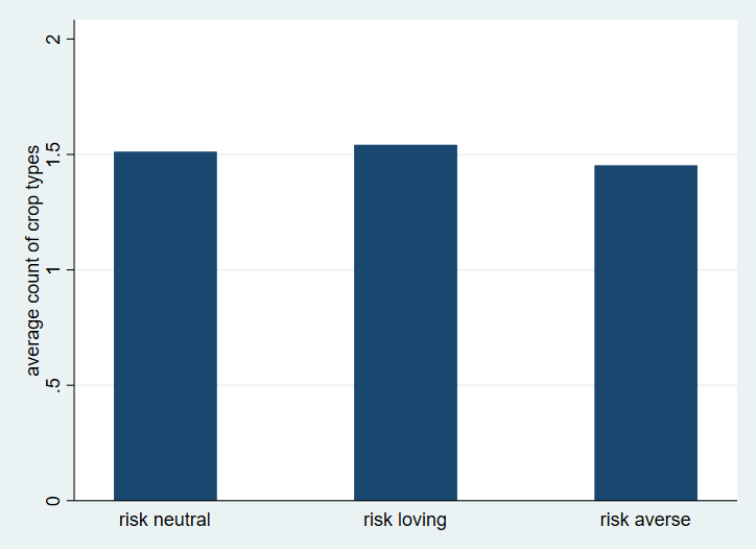
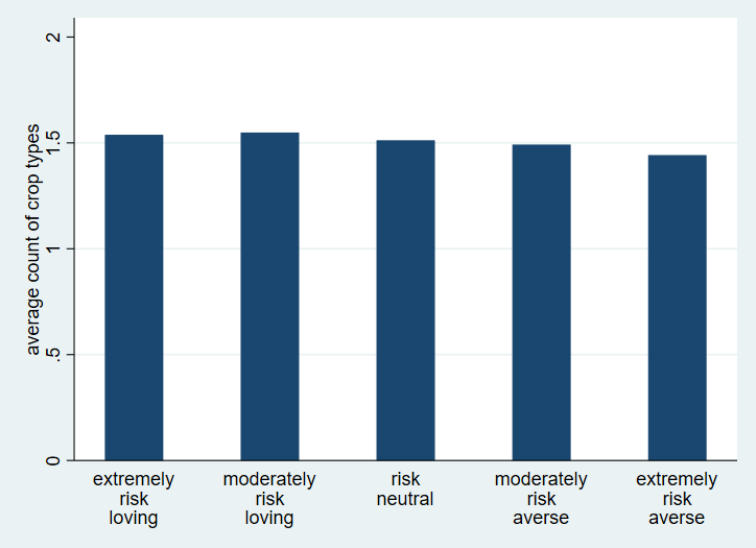
Appendix A: Figures and Tables



(a) Three-category risk measure



(b) Five-point ratings of risk

Figure 1: Risk preference and the average count of crop types on the farm

Table 1: Mean statistics for rural households in the CHFS sample

	2011	2013	2015
Panel A: Household demographics			
Family size	3.87	4.02	3.90
Number of laborers engaged in farming	2.04	1.99	1.99
Panel B: Economic activities			
HH engaged in farming (1=yes)	0.73	0.72	0.73
Total categories of crops	1.62	1.42	1.46
Gross farm income ($\times 10^3$ yuan)	10.60	15.11	18.27
Duration of farming season (months)	7.15	7.04	7.12
HH received government subsidy (1=yes)	0.87	0.79	0.74
HH received bank loan (1=yes)	0.08	0.08	0.06
HH started own business off farm (1=yes)	0.10	0.09	0.10
Observations	3244	8932	11654

Source: CHFS 2011-2015. Seven yuan approximately equals one USD.

Table 2: Household types based on crop selection

	2011	2013	2015
HH Type of crop choices			
Food crops only	1,183 (36.47%)	3,892 (43.57%)	3,222 (27.65%)
Cash crops only	204 (6.29%)	659 (7.38%)	481 (4.13%)
Food crops and cash crops	914 (28.18%)	1,644 (18.41%)	1,351 (11.59%)
All other products	943 (29.07%)	2,737 (30.64%)	6,600 (56.63%)
Total	3,244 (100%)	8,932 (100%)	11,654 (100%)

Source: CHFS 2011-2015.

Table 3: Risk preference and farm diversification

	Farm diversification (1=yes)			
	(1)	(2)	(3)	(4)
Panel A: Risk preference (Three categories)				
- risk loving	0.0012	0.0024		
	(0.0157)	(0.0172)		
- risk averse	-0.0318***	-0.0347***		
	(0.0103)	(0.0113)		
Panel B: Risk preference (Five-point ratings)				
- extremely risk loving			-0.0063	0.0069
			(0.0182)	(0.0197)
- moderately risk loving			0.0154	-0.0066
			(0.0235)	(0.0262)
- moderately risk averse			-0.0235*	-0.0123
			(0.0136)	(0.0148)
- extremely risk averse			-0.0340***	-0.0410***
			(0.0106)	(0.0116)
Household controls	No	Yes	No	Yes
Household FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	16496	12671	16496	12671

Note: Standard errors in parentheses. Single asterisk (*) represents significance at the 10% level, double asterisk (**) significance at the 5% level, and triple asterisk (***) significance at the 1% level. Base group for both panels: households that stated a risk neutral preference. Household controls include the number of household laborers engaged in farming, duration of the last farming season, whether household received government subsidy on farming, whether household received bank loan for farming, and whether household started its own business off farm.

Table 4: Risk preference and total count of crop types

	Total count of crop types on the farm			
	(1)	(2)	(3)	(4)
Panel A: Risk preference (Three categories)				
- risk loving	0.0301	0.0189		
	(0.0230)	(0.0231)		
- risk averse	-0.0591***	-0.0538***		
	(0.0152)	(0.0152)		
Panel B: Risk preference (Five-point ratings)				
- extremely risk loving			0.0265	0.0186
			(0.0264)	(0.0265)
- moderately risk loving			0.0375	0.0199
			(0.0351)	(0.0353)
- moderately risk averse			-0.0202	-0.0261
			(0.0198)	(0.0199)
- extremely risk averse			-0.0698***	-0.0615***
			(0.0156)	(0.0156)
Household controls	No	Yes	No	Yes
Household FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	13167	12671	13167	12671

Note: Standard errors in parentheses. Single asterisk (*) represents significance at the 10% level, double asterisk (**) significance at the 5% level, and triple asterisk (***) significance at the 1% level. Base group for both panels: households that stated a risk neutral preference. Household controls include the number of household laborers engaged in farming, duration of the last farming season, whether household received government subsidy on farming, whether household received bank loan for farming, and whether household started its own business off farm.

Table 5: Risk preference and specific crop choices

	HH type based on crop choices			
	(1)	(2)	(3)	(4)
Panel A: Cash crops only (HH type = 2)				
risk loving	0.1151	0.0577		
	(0.1159)	(0.1216)		
risk averse	-0.1829**	-0.1755**		
	(0.0790)	(0.0826)		
extremely risk loving			0.1842	0.1379
			(0.1305)	(0.1370)
moderately risk loving			-0.0372	-0.1170
			(0.1834)	(0.1927)
moderately risk averse			-0.0190	-0.0265
			(0.1026)	(0.1071)
extremely risk averse			-0.2291***	-0.2186**
			(0.0815)	(0.0853)
Panel B: Food and cash crops (HH type = 3)				
risk loving	0.0102	-0.0092		
	(0.0800)	(0.0825)		
risk averse	-0.1489***	-0.1484***		
	(0.0527)	(0.0544)		
extremely risk loving			0.0241	0.0064
			(0.0920)	(0.0948)
moderately risk loving			-0.0177	-0.0401
			(0.1219)	(0.1260)
moderately risk averse			-0.0182	-0.0509
			(0.0687)	(0.0712)
extremely risk averse			-0.1849***	-0.1754***
			(0.0541)	(0.0559)
Panel C: All other products (HH type = 4)				
risk loving	-0.0114	-0.0671		
	(0.0806)	(0.1995)		
risk averse	-0.1284**	-0.4134***		
	(0.0528)	(0.1365)		
extremely risk loving			-0.1200	-0.0993
			(0.0956)	(0.2333)
moderately risk loving			0.1734	-0.0061
			(0.1162)	(0.2925)
moderately risk averse			-0.2147***	-0.1256
			(0.0714)	(0.1769)
extremely risk averse			-0.1077**	-0.5046***
			(0.0540)	(0.1427)
Household controls	No	Yes	No	Yes
Household RE	Yes	Yes	Yes	Yes
Year RE	Yes	Yes	Yes	Yes
Observations	16496	12671	16496	12671

Note: Standard errors in parentheses. Single asterisk (*) represents significance at the 10% level, double asterisk (**) significance at the 5% level, and triple asterisk (***) significance at the 1% level. Results are derived from multinomial logit regressions (base group: households that choose food crops only). Household controls include the number of household laborers engaged in farming, duration of the last farming season, whether household received government subsidy on farming, whether household received bank loan for farming, and whether household started its own business off farm. Other farm products refer to those harvested from animal husbandry, forestry, and fishery businesses.

Appendix B: Derivations of the Theoretical Model

This appendix presents the detailed derivations of the theoretical framework presented in Section 2. I discuss why crop choice matters in the study of risk preference on the decision of farm diversification, under three different scenarios based on the representative farm household's risk preference.

B.1 Risk Neutral Preference

First, I begin with the case of risk neutrality. That is, $U(R) = R$. We would also need to assign specific forms to the production function of food and cash crops. For simplicity, I assume the following functional form of the production technology: $f(T) = t \cdot log(T+1)$ and $g(T) = s \cdot log(T+1)$, where $f(T)$ and $g(T)$ denote the production technology with respect to farm acreage (T) for food and cash crops, respectively. With this assigned functional form of the production technology, we have $f(0) = g(0) = 0$. Compared with cash crops, food crops usually have a higher yield per acre. As such, I assume that $t > s > 0$. Also, in Section 2 of the main text, I have already assumed that food crops face a smaller range of price fluctuation than cash crops, i.e. $\epsilon \in [-a, a]$ $(0 < a \leq 1)$, $\eta \in [-1, 1]$. In contrast, cash crops have a higher unit price p $(p > 1)$. On the other hand, both R_A and R_B can possibly drop to zero when the adverse shock is quite detrimental. Finally, assume the representative household faces no constraints on agricultural labor and capital inputs. Then, the expected payoff for different three different planting options can be denoted by:

$$
\begin{aligned}
EU_A &= \int_{-a}^{a} [t(1-\epsilon) \cdot log(T+1)] d\epsilon = 2at \cdot log(T+1) \\
EU_B &= \int_{-1}^{1} [ps(1-\eta) \cdot log(T+1)] d\eta = 2ps \cdot log(T+1) \\
EU_C &= \int_{-a}^{a} \int_{-1}^{1} [t(1-\epsilon) \cdot log((1-\delta)T+1) + ps(1-\eta) \cdot log(\delta T+1)] d\eta d\epsilon \\
&= \quad 4at \cdot log((1-\delta)T+1) + 4aps \cdot log(\delta T+1)
\end{aligned}
$$

A rational household decision-maker would compare the expected utility derived from the three crop choices. The optimal choice is specialization if either of EU_A and EU_B is greater than EU_C. Otherwise, if EU_C turns out to be the highest, the representative

household chooses diversification.

By assumption, we have $p > 1 \geq a > 0$ and $t > s > 0$. Thus, it is still uncertain whether at or ps is larger in magnitude. If $at > ps$, we have $EU_A > EU_B$, option A (food crops) is preferred. If $at < ps$, then $EU_B > EU_A$, which means option B (cash crops) is preferred. That is, with risk neutral preference, when the unit yield of food crops is much larger than cash crops, but the price of food crops is not significantly lower, a rational farm household should choose food crops over cash crops. Otherwise, if the unit price of cash crops is much higher than food crops, yet the unit yield of cash crops is not significantly lower, the household should choose cash crops.

If $at = ps$, then $EU_A = EU_B$ and the household should be indifferent between food and cash crops. In this case, I continue to compare EU_C with either of EU_A or EU_B. For example, the numerical difference between EU_C and EU_B can be denoted as:

$$\begin{aligned} EU_C - EU_B = &\quad 4ps \cdot [log((1-\delta)T + 1) + log(\delta T + 1)] - 2ps \cdot log(T + 1) \\ = &\quad 2ps \cdot log[(1 + \frac{\delta(1-\delta)T^2}{T+1})(\delta(1-\delta)T^2 + T + 1)] > 0 \end{aligned}$$

Therefore, with a risk neutral preference, a household should always choose to diverse between food and cash crops on its farm, if the expected utility from planting either of the two crops is identical.

The main takeaway from the derivation process above is that the decision of farm diversification versus specialization is strongly correlated between the crop choices, given a risk neutral risk preference. When the household has no preference, it is always rational to diverse between the two crops. Relatedly, the choice between food crops versus cash crops depends on the unit price and yield of the two types of crops. Normally food crops have a higher yield while cash crops have a higher unit price. When the yield difference outweighs the price difference, the household should choose food crops. On the other hand, if price difference outweighs yield difference, cash crops are the optimal option.

B.2 Risk Averse Preference

Second, I examine the optimal crop choice given a risk averse preference, which is characterized by the following utility function: $U(R) = \frac{1-e^{-\gamma R}}{\gamma}$ $(\gamma > 0)$. As in the case

with risk neutral preference, I still assume that the production technology for food crops and cash crops are represented by $f(T) = t \cdot log(T+1)$ and $g(T) = s \cdot log(T+1)$, respectively ($t > s > 0$). With the assumptions on the functional forms of risk preference and production technology, I compute the representative household's expected utility when it chooses to specialize in one crop and when it prefers to diverse farm production across the two crops, which is denoted as follows:

$$
\begin{aligned}
EU_A &= \int_{-a}^{a} \frac{1-e^{-\gamma f(T)(1-\epsilon)}}{\gamma} d\epsilon = \int_{-a}^{a} [\frac{1}{\gamma} - \frac{e^{-\gamma f(T)(1-\epsilon)}}{\gamma}] d\epsilon \\
&= \frac{2a}{\gamma} - \frac{e^{-\gamma f(T)(1-a)} - e^{-\gamma f(T)(1+a)}}{\gamma^2 f(T)} \\
&= \frac{2a}{\gamma} - \frac{(T+1)^{-\gamma t(1-a)} - (T+1)^{-\gamma t(1+a)}}{\gamma^2 t \cdot log(T+1)} \\
EU_B &= \int_{-1}^{1} \frac{1-e^{-\gamma g(T) \cdot p(1-\eta)}}{\gamma} d\eta = \int_{-a}^{a} [\frac{1}{\gamma} - \frac{e^{-\gamma g(T) \cdot p(1-\eta)}}{\gamma}] d\eta \\
&= \frac{2}{\gamma} - \frac{1-e^{-2\gamma p \cdot g(T)}}{\gamma^2 p \cdot g(T)} = \frac{2}{\gamma} - \frac{1-(T+1)^{-2\gamma ps}}{\gamma^2 ps \cdot log(T+1)} \\
EU_C &= \int_{-a}^{a} \int_{-1}^{1} \frac{1-e^{-\gamma[f((1-\delta)T) \cdot (1-\epsilon) + g(\delta T) \cdot p(1-\eta)]}}{\gamma} d\eta d\epsilon \\
&= \frac{4a}{\gamma} - \frac{[1-e^{-2\gamma p \cdot g(\delta T)}] \cdot [e^{-\gamma f((1-\delta)T)(1-a)} - e^{-\gamma f((1-\delta)T)(1+a)}]}{\gamma^2 p \cdot f((1-\delta)T) \cdot g(\delta T)} \\
&= \frac{4a}{\gamma} - \frac{[1-(\delta T+1)^{-2\gamma ps}] \cdot [((1-\delta)T+1)^{-\gamma t(1-a)} - ((1-\delta)T+1)^{-\gamma t(1+a)}]}{\gamma^2 pst \cdot log((1-\delta)T+1) \cdot log(\delta T+1)}
\end{aligned}
$$

The rigorous comparison of the expected utility based on the three options can be complicated. I consider a simplified setting where cash crops face the same level of price fluctuation with food crops ($a = 1$). In this case, $EU_A = \frac{2}{\gamma} - \frac{1-(T+1)^{-2\gamma t}}{\gamma^2 t \cdot log(T+1)}$. The comparison between EU_A and EU_B depends solely on the relationship between ps and t. The discussion is similar to the setting of a risk neutral preference.

If I further assume $ps = t$, then the household is indifferent between food and cash crops. In this case, it is not difficult to find that $EU_C > EU_A$ and $EU_C > EU_B$. Therefore, the household should choose to diverse. This finding is the same as what I find with a risk neutral preference.

B.3 Risk Loving Preference

Last but not least, I investigate whether and how things change for households with a risk loving preference. In fact, this case is quite similar to the risk averse setting, the utility function also looks like $U(R) = \frac{1-e^{-\gamma R}}{\gamma}$, but now I assume $\gamma < 0$ to indicate the risk loving preference. Notice that the sign of γ only affects the comparison between EU_A and EU_B. When the household is indifferent between food and cash crops, it is always rational to cultivate the two types of crop at the same time.

To conclude, in this appendix, I find a nontrivial connection between specific crop choices and the decision of farm diversification through the derivations of the theoretical framework presented in the main text. Prior to examining the impact of risk attitudes on the decision of farm diversification, probably it is wise to check whether the household exhibits any specific preference for a certain crop type, either for risk management or for ensuring food self-sufficiency. This kind of crop preference could potentially affect farmers' decision on diversification versus specialization, making the estimated effect of risk preference on the decision of farm diversification less informative. Therefore, it is wise to consider risk preference, crop choice and the decision of farm diversification as a unified system and make necessary adjustments to the empirical design accordingly.