The Asymmetric Response of Farmers to the Expected Change of Rubber Price: the Roles of Sunk Cost and Path Dependency

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Abstract:

This study examines the impacts of sunk cost and path dependency on farmers' responses to the expected price change. A simple choice experiment was implemented to collect the responses of farmers to the hypothetical change in rubber price. The results show that near 73% of farmers choose to adjust their productive behaviors when rubber price is hypothesized to increase by 50%, while it is only about 55% when rubber price is hypothesized to increase by 50%. The responses of farmers to these two hypothetical changes in rubber price are significantly asymmetrical. The sunk cost and path dependency of rubber farming are proxied by the planting area of and experience in rubber farming, respectively. The estimation results of a bivariate probit model indicate that the higher sunk cost and longer path dependency of rubber farming significantly hinder farmers' probabilities to adjust their productive behaviors in the response to the two hypothetical changes in rubber price. The significant difference in the impacts of sunk cost and path dependency on the choice of response behaviors under the two hypothetical situations may help to explain the observed asymmetric response. The impacts of sunk cost and path dependency on the choice of specific productive adjusting behavior are heterogeneous.

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JEL Codes: Q11, Q21

#1643

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Abstract:

This study examines the impacts of sunk cost and path dependency on farmers' productive response to the expected price change. A simple choice experiment was implemented to collect the responses of smallholder rubber farmers in upper Mekong region to the hypothetical change in rubber price. The results show that near 73% of farmers choose to adjust their productive behaviors when the price of rubber is hypothesized to increase by 50%, while it is only about 55% when the price of rubber is hypothesized to increase by 50%. The responses of farmers to these two hypothetical changes in rubber price are significantly asymmetrical. The sunk cost and path dependency of rubber farming are proxied by the planting area of and experience in rubber farming, respectively. The estimation results of a bivariate probit model indicate that the higher sunk cost and longer path dependency of rubber farming significantly hinder smallholder farmers' probabilities to adjust their productive behaviors in the response to the two hypothetical changes in rubber price. The significant difference in the impacts of sunk cost and path dependency on the choice of response behaviors under the two hypothetical situations may help to explain the observed asymmetric response to some extent. Also, the impacts of sunk cost and path dependency on the choice of specific productive adjusting behavior are heterogeneous.

Keywords: Rubber farming; Sunk cost; Path dependency; Asymmetric response

JEL classification: D13; Q11

1. Introduction

The response of farmers to the price volatility of agricultural product is an important research issue related to farmers' welfare and agricultural product supply. Modern economic theories normally assume that a rational farmer will adjust their agricultural production behaviors to maximize profits according to the previous market price (Ezekiel, 1938; Waugh, 1964), the adaptive expectation of price (Nerlove, 1956; Nerlove, 1958), or the rational expectation of price (Muth, 1961; Lucas and Rapping, 1969; Lucas and Prescott, 1971). However, the rationality assumption for a farmer's price response behavior may be challenged in case of agricultural products with long production periods, such as trees, perennial crops, and animals. On the one hand, the long production period of such agricultural product makes their future price difficult to be expected; while the likely resulting path dependence may also affect farmers' decision-making (Arthurs, 1989; David, 1994). On the other hand, the relatively high initial investment cost of such agricultural product may also lead to an irrational economic behavior of farmers, which could be termed the sunk cost effect (Arkes and Blumerp, 1985). It means that a farmer's price response behavior is not only determined by the extent of price change but also affected by the prior investments in rubber farming.

While the price responses of agricultural products (Houck and Paul, 1976; Willett et al., 1997; Haile et al., 2015) and the possible causes of asymmetric price adjustment have been widely discussed in previous studies (Chavas et al., 2004; Meyer and Stephan, 2004), the study focusing on the response of rubber farmers to the change of rubber (latex) price is lacking.[1] Generally, in the presence of adjustment cost, firms may not respond to small or transitory price changes until the benefits of changing strategies outweigh the cost (Chavas et al., 2004). The price response behavior was significantly influenced by non-proportional variable transaction costs and labor heterogeneity (Henning and Henningsen, 2007). In the early studies (Dowling 1979; Hartley et al., 1987), the supply response for the rubber to the

[1] For the simplicity, in the rest of the study, the price of rubber represents the price of latex.

volatility of rubber price was well explored using time series data. However, from the perspective of the micro household level, farmers' response to the volatility of rubber price is still unclear. While sunk costs could create irreversibility in firms' strategies (Dixit and Pindyck, 1994), the impact of sunk cost on rubber farmers' price response behavior is unidentified. Also, the possible impact of path dependency as growing rubber for a long time is also unknown.

This study attempts to empirically test the existence of sunk cost effect in the response of farmers to the price fluctuation of agricultural product and examine the impact of path dependence. To achieve it, we conducted a simple choice experiment among smallholder rubber farmers in early 2013 in Xishuangbanna, Southwest China, Upper Mekong region. Natural rubber is a kind of tropical agroforestry products with a long production period around 35 years, normally grows about 6-8 years before being harvested (Min et al., 2017a), and thereby provides a unique opportunity to support this study. A choice experiment was implemented to collect the responses of farmers to the expected change in rubber price. We focus on exploring farmers' response behaviors under two cases of expected change in rubber price: (i) decrease by 50%, and (ii) increase by 50%. The assumption of these two relatively large change magnitudes contributes to as much as possible observe the variances in farmers' response behaviors.

The results show an asymmetric response of farmers to the hypothetical change of rubber price. Near 73% of smallholder rubber farmers choose to adjust their productive behaviors when the price of rubber is hypothesized to increase by 50%, while it is only about 55% when the price of rubber is hypothesized to decrease by 50%. The sunk cost and path dependency negatively affect farmers' decisions to adjust their productive behaviors when the price of rubber is hypothesized to either increase or decrease, while the heterogeneity in their impact magnitudes is a reason for the observed asymmetric response. As for the specific choice of productive adjusting behaviors, the impacts of sunk cost and path dependency are different.

The study provides a novel insight into a better understanding of smallholder rubber farmers' production behavior in the response to the price fluctuation. This paper adds to the existing literatures in the price response behavior of farmers with regard to perennial crops, trees, animals and other similar products with relatively long production period (Chavas et al., 1985; Price and Wetzstein, 1999; Foltz, 2004) and the roles of sunk cost and path dependence in farmers' agricultural production behaviors (Chavas, 1994;Cowanand Gunby, 1996).

The rest of this paper is organized as follows: in section 2, a conceptual model related to the impacts of sunk cost and path dependency on smallholder rubber farmers' decision-making is developed. Section 3 briefly presents the study area and the data collection procedure as well as descriptive statistics. Section 4 describes the empirical models developed to assess the likelihood that smallholders adjust their productive behaviors in the response to the change of rubber price. In Section 5, we report and discuss the results of our models. The last section consists of a summary and conclusions.

2. Conceptual model

The farmer is assumed to plant natural rubber, which generally can be harvested after growing for 6-8 years. Hence, there exists a certain sunk cost of rubber farming. As a rubber tree averagely can be harvested over 30 years, the long experience of rubber farming also results in a certain path dependency for farmers on the rubber farming. Assume the price of rubber changes, theoretically, a rational farmer responds to price changes by adjusting his productive behaviors of rubber farming e.g. changing the number of tapping days or the daily number of trees tapped (Stifel, 1975) and thereby re-maximize the profits of rubber farming. However, the existence of the sunk cost and path dependency of rubber farming may influence a farmer's response to the change of rubber price.

Based on the definitions of sunk cost and path dependency in previous studies (Arkes and Blumerp, 1985; Arthurs, 1989; David, 1994), sunk costs are supposed to be a proportion

of fixed costs (Baumol, Panzar, and Willig 1983) and should increase with farm size (Adelaja,1991). Thus, the sunk cost (*SC*) of rubber farming can be assumed to be a function of the unit fix cost of rubber farming (*C*) and rubber planting area (*A*) , while the path dependency (*PD*) of rubber farming is supposed to be a function of the experience in rubber farming (*E*). Therefore, the sunk cost and path dependency of rubber farming can be written as:

$$SC = f(C, A|\boldsymbol{Z}) \tag{1}$$

$$PD = g(E|\boldsymbol{Z}) \tag{2}$$

where $\boldsymbol{Z}$ is a vector of farmers' and farms' characteristics. The unit fix cost of rubber farming (*C*) is assumed to be determined by $\boldsymbol{Z}$**,** thus, equation (1) can be simplified as:

$$SC = f(A|\boldsymbol{Z}) \tag{3}$$

Suppose equations (2) and (3) are the increment functions of *A* and *E*, respectively; therefore, the sunk cost of rubber farming can be proxied by the planting area of rubber farming (*A*), while the path dependency of rubber farming can be proxied by the experience in rubber farming (*E*).

Assume the price of rubber in the next period (p_{t+1}) is expected to be a certain portion (α) of the current price (p_t), i.e. $p_{t+1} = \alpha * p_t$. A vector of the market prices of the inputs of rubber farming are assumed to be $\boldsymbol{P}_{t+1}$, while the profit of rubber farming is determined by the prices of rubber and inputs as well as $\boldsymbol{Z}$**.** The profit of rubber farming without adjusting productive behaviors of rubber farming is $\pi_{t+1}(p_{t+1}, \boldsymbol{P}_{t+1}, \boldsymbol{Z})$, while profit with adjusting productive behaviors is $\pi'_{t+1}(p_{t+1}, \boldsymbol{P}_{t+1}, \boldsymbol{Z})$. Generally, when the price of rubber is expected to change from p_t to p_{t+1} , the farmer will make a decision on whether adjusting his productive behavior of rubber farming by making a trade-off between the expected profits $\pi_{t+1}(p_{t+1}, \boldsymbol{P}_{t+1}, \boldsymbol{Z})$ and $\pi'_{t+1}(p_{t+1}, \boldsymbol{P}_{t+1}, \boldsymbol{Z})$. Assume a latent variable D^*, which represents $\pi'_{t+1}(p_{t+1}, \boldsymbol{P}_{t+1}, \boldsymbol{Z}) - \pi_{t+1}(p_{t+1}, \boldsymbol{P}_{t+1}, \boldsymbol{Z})$. Thus, the farmer's decision on whether adjusting the productive behavior (*D*) in the response to the change of rubber price could be written as:

$$D = \begin{cases} 1 & if \quad D^* > 0 \\ 0 & if \quad otherwise \end{cases} \tag{4}$$

where D=1 indicates that the farmer decides to adjust productive behavior; otherwise D=0. Then, the probability of adjusting the productive behavior can be further expressed as:

$$Pr(D = 1) = Pr\ (D = 1|\alpha, p_t, \boldsymbol{P}_{t+1}, \boldsymbol{Z}) \tag{5}$$

As p_t and $\boldsymbol{P}_{t+1}$ can be assumed to be consistent among all the rubber farmers, they are further eliminated from equation (5).

As we are interested in assessing the effects of sunk cost and path dependence on farmers' response to the expected change of rubber price, *SC* and *PD* are then directly incorporated into equation (5):

$$Pr(D = 1) = Pr(D = 1|\alpha, SC, PD, \boldsymbol{Z}) \tag{6}$$

By further incorporating equations (2) and (3), the equation (6) can be expressed as:

$$Pr(D = 1) = Pr(D = 1|\alpha, A, E, \boldsymbol{Z}) \tag{7}$$

As the sunk cost (*SC*) and path dependency (*PD*) of rubber farming can be proxied by the planting area (*A*) of and experience (*E*) in rubber farming, respectively; the partial derivatives $\partial Pr(D = 1)/\partial A$ and $\partial Pr(D = 1)/\partial E$ reflect the impacts of *SC* and *PD* on the probability of adjusting productive behavior in the response to the price change of rubber.

3. Data

3.1. Data collection

Data used in this study was obtained from a comprehensive socioeconomic survey of 612 smallholder rubber farmers in Xishuangbanna Dai Autonomous Prefecture of Southern Yunnan province in China conducted in early 2013. Xishuangbanna is located in the upper Mekong region, is one of the most important natural rubber planting regions in China, and contributes nearly half of the nation's rubber production (Min et al., 2017a). The introduction of natural rubber has also contributed to the local economy by improving farmer income and reducing poverty (Min et al, 2017b). However, in the context of recently price volatility of

natural rubber, the poverty and vulnerability to poverty likely constitute a potentially severe threat for many smallholders (Min et al., 2017a).

During the survey, we used a comprehensive household questionnaire including detailed information on socioeconomic characteristics of all family members, household, and farm. Furthermore, we conducted a simple choice experiment to investigate smallholder farmers' productive adjusting behaviors in the response to the hypothetical change of rubber price. We used two main survey questions as follows: (i) If in the next 10 years the price of natural rubber will decrease by 50%, what will you respond? (1. No response / do nothing; 2. Rent out rubber land; 3. Change rubber plantation to plant other crops; 4. Reduce variable cost input; 5. Other, please specify); (ii) If in the next 10 years the price of natural rubber will increase by 50%, what will you respond? (1. No response / do nothing; 2. Rent in rubber land; 3. Change other crops to rubber plantation; 4. Increase variable cost input; 5. Other, please specify). In this study, we primly focus on exploring whether farmers will respond to the change of rubber price, and secondly concern the choice of the specific adjustment behaviors.

3.2. Descriptive statistics

Table 1 presents the survey results regarding farmers' responses to the hypothetical change of rubber price and the comparisons of them by the three quantiles of path dependency and sunk cost of rubber farming. Despite rubber price change objectively should influence farmers' rubber production behaviors (Etherington, 1977), but our experimental results show that if rubber price is expected to decrease by 50%, about 56 % of farmers tend to adjust their production behaviors; whereas it is near 74% if rubber price is expected to increase by 50%. When the price of rubber is hypothesized to decrease by 50%, over 38% of farmers are prepared to reduce rubber inputs, near 34% of farmers are going to plant other crops by replacing rubber, and about 27% of farmers tend to rent out rubber plantations. When the price of rubber is hypothesized to increase by 50%, over 52% of farmers tend to increase rubber inputs, about 48% of farmers plan to rent in more rubber plantations, and about 34% of

farmers are prepared to plant more rubber trees by replacing other crops. Overall, the results indicate that smallholder farmers are more sensitive to the increase in rubber price.

Table 1: Farmers' responses to the hypothetical change of rubber price and the comparisons of them by the three quantiles of path dependency and sunk cost of rubber farming

Categories	Obs.	% response if rubber price is expected to…							
		decrease by 50%				increase by 50%			
		Either	Rent out	Rubber -crops	Reduce inputs	Either	Rent in	Crops -rubber	Increase inputs
All samples	612	56.30	27.12	33.66	38.40	73.90	48.37	34.15	52.45
3 quantiles of path dependence (experience in rubber farming)									
1st Q (1-12 years)#	209	60.29	29.19	35.89	38.28	75.60	47.37	37.32	55.02
2nd Q (13-21 years)	213	56.34	26.29	32.39	38.97	76.53	51.64	33.80	53.99
3rd Q (22+ years)	190	52.11*	25.79	32.63	37.89	68.95*	45.79	31.05*	47.89*
3 quantiles of sunk cost (planting area of rubber farming)									
1st Q (0.24-5.33 ha)#	204	58.33	28.43	33.33	43.14	76.47	28.43	33.33	43.14
2nd Q (5.33-10.70 ha)	206	54.85	27.67	34.95	36.41*	74.76	27.67	34.95	36.41
3rd Q (10.71+ ha)	202	55.94	25.25	32.67	35.64*	70.30	25.25	32.67	35.64**

Note: *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. The statistical test used is the mean-comparison test between the group and the reference group # in each category.

On average, the planting area of rubber as the proxied variable for sunk cost of rubber farming was about 0.7 ha/household, while the proxied variable for path dependency - the experience in rubber farming was over 17 years. As shown in Table 1, the results suggested that both a longer path dependency and a higher sunk cost of rubber farming resulted in a lower response rate to the change of rubber price, regardless of increase or decrease in rubber price. However, the differences in response rate between the lowest quantile and the highest quantile were statistically significant in only several categories.

4. Empirical model

To more accurately capture the impacts of sunk cost and path dependency on farmers' response to the hypothetical change of rubber price, in this section we develop two empirical models including a probit model and a bivariate probit model according to the proposed conceptual model. Also, a multivariate probit model is employed to assess farmers' choice of specific response behaviors.

First, based on a standard probit model, the equation (7) can be further expressed as:

$$Pr(D=1) = Pr(D=1|\alpha, A, E, \boldsymbol{Z}) = \Phi(\rho_0 + \rho_1\alpha + \rho_2 A + \rho_3 E + \rho_4 \boldsymbol{Z}) \quad (8)$$

where $\Phi(\cdot)$ is the cumulative normal distribution. Thus, the log-likelihood function for the equation (8) is:

$$\ln L = \sum\{D\ln[\Phi(\rho_0 + \rho_1\alpha + \rho_2 A + \rho_3 E + \rho_4 \boldsymbol{Z})] + (1-D)\ln[1 - \Phi(\rho_0 + \rho_1\alpha + \rho_2 A + \rho 3E + \rho 4\boldsymbol{Z})] \quad (9)$$

The equation (9) is supposed to be estimated using maximum likelihood estimation, and then the parameters for each independent variables can obtain.

For the second empirical model, we set a system with two equations respectively representing a farmer's response to the price increase and decrease, as follows:

$$\begin{cases} Pr(D=1) = \Phi(\rho_0 + \rho_2 A + \rho_3 E + \rho_4 \boldsymbol{Z}) & if \quad \alpha = 1 \\ Pr(D=0) = \Phi(\rho_0 + \rho_2 A + \rho_3 E + \rho_4 \boldsymbol{Z}) & if \quad \alpha = 0 \end{cases} \quad (10)$$

where $\alpha = 1$ represents when the price of rubber is hypothesized to increase by 50%, while $\alpha = 0$ denotes when the price is hypothesized to decrease by 50%. Considering the potential correlation between error terms of the two equations in the system (10), which is estimated by a standard bivariate regression using maximum likelihood estimation.

Finally, for the choice of specific response behaviors, two systems can be established for the choices under the two hypothetical changes of rubber price including decrease 50% ($\alpha = 0$) and increase by 50% ($\alpha = 1$):

$$\begin{cases} Pr(rentout = 1) = \Phi(\rho_0 + \rho_2 A + \rho_3 E + \rho_4 \boldsymbol{Z}) \\ Pr(crops = 1) = \Phi(\rho_0 + \rho_2 A + \rho_3 E + \rho_4 \boldsymbol{Z}) \\ Pr(reduce = 1) = \Phi(\rho_0 + \rho_2 A + \rho_3 E + \rho_4 \boldsymbol{Z}) \end{cases} \quad if \quad \alpha = 0 \quad (11)$$

$$\begin{cases} Pr(rentin = 1) = \Phi(\rho_0 + \rho_2 A + \rho_3 E + \rho_4 \boldsymbol{Z}) \\ Pr(rubber = 1) = \Phi(\rho_0 + \rho_2 A + \rho_3 E + \rho_4 \boldsymbol{Z}) \\ Pr(increase = 1) = \Phi(\rho_0 + \rho_2 A + \rho_3 E + \rho_4 \boldsymbol{Z}) \end{cases} \quad if \quad \alpha = 1 \quad (12)$$

In the system (11), wherein $rentout = 1$ represents "rent out rubber plantations", otherwise $rentout = 0$; $crops = 1$ means "plant other crops by replacing rubber plantations", otherwise $crops = 0$; $reduce = 1$ denotes "reduce the inputs of rubber farming", otherwise $reduce = 0$. In the system (12), $rentin = 1$ represents "rent in rubber plantations", otherwise

$rentin = 0$; $rubber = 1$ means "plant more rubber plantations by replacing other crops ", otherwise $rubber = 0$; $increase = 1$ denotes "increase the inputs of rubber farming", otherwise $increase = 0$. The systems (11) and (12) are supposed to be estimated by a multivariate probit regression using maximum likelihood estimation.

The significance of ρ_1 in equation (8) can identify whether farmers' responses between price increase and price decrease are symmetrical. The parameters ρ_2 and ρ_3 in the systems (10), (11) and (12) denote the impacts of sunk cost and path dependence on farmers' price response decision, respectively.

Table 2: Summary statistics of key independent variables

Variables	All samples	Respond if rubber price is expected to…			
		decrease by 50%		increase by 50%	
		Yes#	No	Yes#	No
Path dependence (Experience in rubber faming (year))	17.21	16.53	18.03**	16.97	17.88
	(8.69)	(8.65)	(8.69)	(8.57)	(9.03)
Sunk cost (Planting area of rubber (hectare))	0.70	0.64	0.79**	0.65	0.87 ***
	(0.76)	(0.50)	(0.98)	(0.57)	(1.11)
Age of respondent (year)	47.98	47.67	48.35	47.75	48.63
	(10.52)	(11.06)	(9.83)	(10.46)	(10.68)
Education of respondent (year)	4.38	4.40	4.35	4.44	4.19
	(3.58)	(3.51)	(3.66)	(3.51)	(3.75)
Household size	5.11	5.17	5.05	5.06	5.26*
	(1.46)	(1.45)	(1.47)	(1.42)	(1.55)
Household wealth (1000 Yuan/person)	69.54	72.35	66.14	72.49	61.20
	(81.07)	(93.61)	(62.66)	(87.87)	(57.14)
Planting area of other crops (hectare)	0.12	0.12	0.13	0.12	0.13
	(0.26)	(0.21)	(0.32)	(0.27)	(0.26)
Observations	612	335	277	452	160

Note: Std. Dev. in parentheses; *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. The statistical test used is the mean-comparison test between the group and the reference group # in each category.

Table 2 presents the independent variables in the empirical models. Apart from the variables of sunk cost and path dependency of rubber farming. We also include the age and education level of respondents. At the household level, the independent variables consist of household size, household wealth (the values of non-farm assets in the household), and the

planting area of other crops. We also check for the correlations of these independent variables and possible collinearity. Although the pairwise correlations of several relevant variables are significant (see correlation matrices in Table A1), the test result of the possible collinearity using VIFs (variance inflation factors) suggests there is no collinearity (see Table A2). As we are prepared to estimate the empirical models by controlling for the village dummy variables, all the independent variables at the village level and above are omitted autonomously.

When rubber price is hypothesized to decrease or increase by 50%, the differences in the mean values of these independent variables between the responding farmers and other farmers provide a brief indication of the significant variables for explaining farmers' decision to respond price change. However, the results in Table 2 show that only sunk cost and path dependency have significant differences between the responding farmers and other farmers. It seems that a farmer with a higher sunk cost and path dependency of rubber farming tend to not respond to the change of rubber price.

5. Estimation results

5.1. Estimation results of a probit regression

Table 3 reports the stepwise probit regression results of the equation (9) using maximum likelihood estimation. The Wald chi^2 tests of all model results (a, b, c and d) are significantly different from zero, validating the specifications of the empirical models. From the results (a) to (d), we gradually add more independent variables, while the variable of price is always significant and positive. This stable result suggests that farmers have a significantly higher probability to adjust their productive behaviors in the response to the increase in rubber price, compared with the response to the decrease in rubber price, although we have set the same change magnitude (50%) of rubber price for these two cases. Therefore, this result reveals the asymmetric responses of smallholder farmers to the change in rubber price. The calculation results of marginal effect further indicate that averagely smallholder farmers have an 18.9%

higher probability to adjust their productive behavior in the response to the 50% increase in rubber price than in the response to the 50% crease in rubber price.

Table 3: Probit regression results for the equation (9)

Variables	(a)		(b)		(c)		(d)		Marginal effects
Price (1=Increase by 50%;	0.520	***	0.528	***	0.531	***	0.572	***	0.189
0=Decrease by 50%)	(0.075)		(0.075)		(0.075)		(0.077)		(0.024)
Path dependence			-0.011	**	-0.014	***	-0.022	***	-0.007
			(0.004)		(0.005)		(0.007)		(0.002)
Sunk cost			-0.211	***	-0.222	***	-0.218	***	-0.072
			(0.051)		(0.050)		(0.056)		(0.018)
Age of respondent					-0.004		-0.005		
					(0.004)		(0.004)		
Education of respondent					0.006		0.021		
					(0.012)		(0.013)		
Household size					0.018		0.031		
					(0.028)		(0.030)		
Household wealth					0.002	***	0.001	***	0.0005
					(0.001)		(0.001)		(0.0001)
Planting area of other crops					-0.059		-0.019		
					(0.153)		(0.186)		
Village dummy variables	No		No		No		Yes		
_cons	0.119	**	0.461	***	0.510	***	0.403		
	(0.051)		(0.101)		(0.256)		(0.356)		
Obs	1224		1224		1224		1224		
Wald chi2	48.55	***	69.390	***	79.340	***	170.440	***	
Pseudo R2	0.0308		0.0445		0.051		0.110		

Notes: *, **, and *** indicate significance at the 1%, 5%, and 10% level, respectively;
Robust standard errors are in parentheses.

Under the situation without considering the change direction of rubber price, Table 3 also shows that the path dependency (experience in rubber farming) and sunk cost (the planting area of rubber plantations) always has significant and negative impacts on the probabilities of farmers to respond to the expected change of rubber price. The results actually confirm the existence of sunk cost effect in rubber farming and reveal the impacts of path dependency. A longer path dependence on rubber farming may limit the capacities of farmers to respond to the volatility of rubber price, while farmers with higher sunk cost in rubber farming seem not rational to adjust their production behaviors in the response to rubber price

change, and tend to be less likely to respond. Farmers with more wealth are more likely to adjust their productive behaviors, implying the importance of capitals in agricultural transformations.

According to the calculation results of marginal effect in Table 3, the experience in rubber farming increases 1 year, the likelihood of responding to the change of rubber price will decrease 0.7%. Increase 1 ha of rubber plantation will decrease 7.2% probabilities of adjusting productive behaviors in the response to the change of rubber price. Household wealth increasing 1 thousand Yuan/ person will increase 0.05% probabilities of responding to the hypothetical change of rubber price.

5.2. Estimation results of a bivariate probit regression

Table 4: Estimation results of a bivariate regression for the system equations (10)

	Decrease by 50%			Increase by 50%		
	Coef.		Marginal effects	Coef.		Marginal effects
Path dependence	-0.027	***	-0.010	-0.021	*	-0.005
	(0.010)		(0.004)	(0.012)		(0.003)
Sunk cost	-0.199	***	-0.078	-0.254	***	-0.060
	(0.074)		(0.029)	(0.085)		(0.020)
Age of respondent	-0.007			-0.003		
	(0.006)			(0.006)		
Education of respondent	0.011			0.037	*	0.009
	(0.018)			(0.020)		(0.005)
Household size	0.074	*	0.029	-0.025		
	(0.040)		(0.016)	(0.043)		
Household wealth	0.001	*	0.001	0.002	**	0.0004
	(0.001)		(0.0003)	(0.001)		(0.0002)
Planting area of other crops	-0.178			0.207		
	(0.224)			(0.369)		
Village dummy variables	Yes			Yes		
_cons	0.325			1.220	**	
	(0.493)			(0.543)		
Obs.			612			
Wald test of rho=0			85.2871	***		
Wald chi2			10528.32	***		

Notes: *, **, and *** indicate significance at the 1%, 5%, and 10% level, respectively.
Robust standard errors are in parentheses.

Table 4 further reports the estimation results regarding the impacts of sunk cost and path dependency on the farmers' response to the 50% decrease and the 50% increase in rubber price, respectively. The result of Wald test of ρ=0 confirms the validity of the application of a bivariate probit model, while the test result of Wald chi^2 approves the joint significances of the independent variables to explain farmers' price response behaviors. According to the estimation results, we further predict the probabilities of responding the decrease and increase in rubber price. As shown in Figure 1, the cumulative distributions of the probabilities of responding to the decrease and increase in rubber price further visibly confirm the asymmetric response of farmers to the expected change of rubber price.

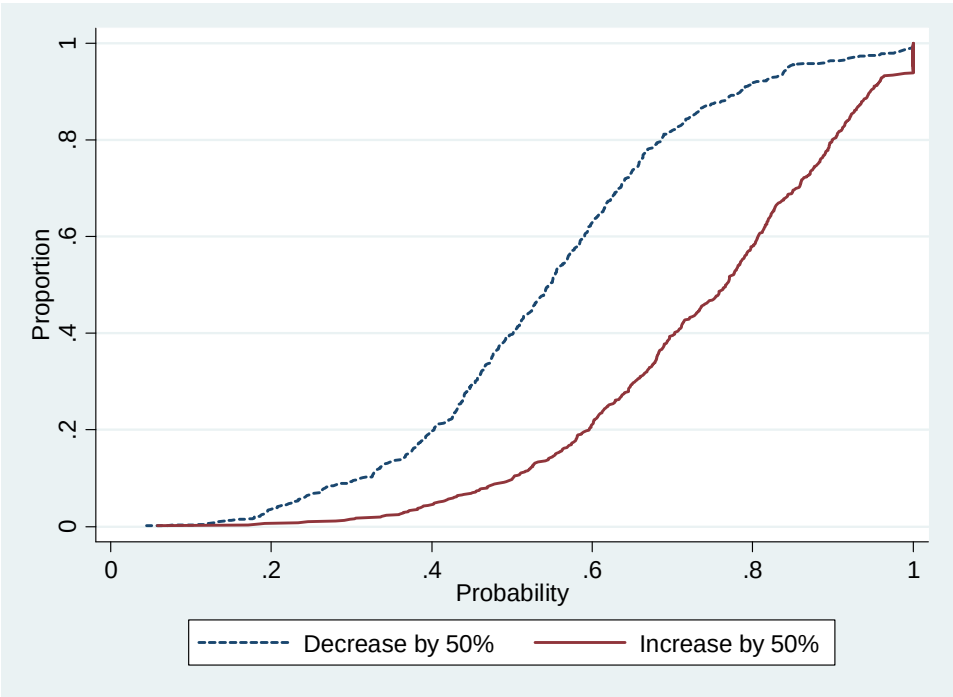

Figure 1: Cumulative distributions of the probabilities of responding to the decrease and increase in rubber price

The results in Table 4 indicate that the sunk cost and path dependency of rubber farming always significantly and negatively affect farmers' decisions to respond to the change of rubber price, regardless of decrease and increase in rubber price. In the case that rubber price is expected to decrease by 50%, the farmers with a higher sunk cost and a longer path dependence on rubber farming are still more difficult to transform. It seems that a higher sunk

cost and path dependence of rubber farming to some extent can make farmers confront greater risks of price fluctuations. Similarly, a higher sunk cost and path dependency of rubber farming significantly hinder farmers to respond to the 50% increase in rubber price, reducing the likelihood to irrationally expand rubber.

Table 5: Decomposition analysis of the asymmetrical response to the expected rubber price change by the path dependency and sunk cost of rubber farming

	When the rubber price is expected to...		Asymmetric	
	decrease by 50%	increase by 50%	Amount	Share (%)
Predicted probability	0.5452	0.7383	-0.1931	100.00
Total effect of the path dependence on the probability to adjust production behavior	-0.1721	-0.0860	-0.0860	44.56
Total effect of the sunk cost on the probability to adjust production behavior	-0.0550	-0.0423	-0.0127	6.57

Data source: Author's calculation

Based on the mean values of the experience in and planting area of rubber farming as well as the marginal effects of path dependency and sunk cost reported in Table 4, a simple decomposition analysis of the asymmetrical response to the expected rubber price change is reported in Table 5. The differences in the marginal effects of sunk cost and path dependency on the choice of response behaviors under the two hypothetical situations can explain over 50% of the asymmetric response rate. In particular, the difference in the total effect of the path dependence of rubber farming occupies about 45% of the asymmetrical response rate.

5.3. Estimation results of a multivariate probit regression

Table 6 reports the estimation results of the two multivariate probit regressions for the system equations (11) and (12). The test results of Wald chi^2 confirm the joint significances of the independent variables to explain farmers' choices of specific response behaviors, while the results of chi^2 tests validate the application of the multivariate probit regressions.

Table 6: Estimation results of a multivariate probit regression for the choice of specific response behaviors to the hypothetical change of rubber price

	Decrease by 50%						Increase by 50%					
	Rent out		Rubber-crops		Reduce inputs		Rent in		Crops-rubber		Increase inputs	
Path dependence	-0.016	*	-0.014		-0.004		-0.010		-0.002		-0.017	*
	(0.010)		(0.009)		(0.009)		(0.009)		(0.010)		(0.009)	
Sunk cost	-0.123		-0.284	**	-0.207	*	-0.133		-0.113		-0.274	**
	(0.108)		(0.130)		(0.110)		(0.089)		(0.105)		(0.111)	
Age of respondent	-0.008		-0.006		-0.013	**	0.004		0.002		-0.010	*
	(0.006)		(0.006)		(0.006)		(0.006)		(0.006)		(0.006)	
Education of respondent	0.003		0.006		-0.018		0.034	*	0.009		0.009	
	(0.019)		(0.018)		(0.017)		(0.018)		(0.018)		(0.017)	
Household size	0.009		0.012		0.080	**	0.002		-0.032		0.012	
	(0.046)		(0.044)		(0.040)		(0.043)		(0.043)		(0.040)	
Household wealth	0.0004		0.001	*	0.000		0.003	***	0.002	**	0.001	*
	(0.001)		(0.001)		(0.001)		(0.001)		(0.001)		(0.001)	
Planting area of other crops	-0.112		-0.339		0.238		-0.241		-0.123		0.263	
	(0.316)		(0.363)		(0.275)		(0.279)		(0.295)		(0.282)	
Village dummy variables	Yes		Yes		Yes		Yes		Yes		Yes	
_cons	-0.421		-0.360		0.370		-1.554	**	-0.813		1.158	**
	(0.583)		(0.562)		(0.466)		(0.648)		(0.570)		(0.463)	
rho21			0.846	***					0.790	***		
			(0.030)						(0.036)			
rho31			0.816	***					0.412	***		
			(0.034)						(0.061)			
rho32			0.694	***					0.662	***		
			(0.044)						(0.044)			
Obs.			612						612			
Wald chi2			211.64	***					190.52	***		
Chi2 (Likelihood ratio test of rho21 = rho31 = rho32 = 0)			382.322	***					342.264	***		

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

The results show the heterogeneous impacts of the path dependency and sunk cost of rubber farming on the choice of specific response behaviors. A longer path dependency of rubber farming makes farmers less likely to rent out rubber plantations when the price of rubber is expected to decrease by 50% and hinders farmers to increase rubber inputs when the price of rubber is hypothesized to decrease by 50%. The sunk cost of rubber farmer negatively affects farmers choices to convert rubber into crops and increase inputs when the price of rubber is expected to decrease, while a higher sunk cost of rubber farming also hinders farmers to increase rubber inputs when rubber price is expected to increase.

5.4. Robustness check

All empirical models in this study control for the village level, while in this section we are to relax the control variables to look at the robustness of the main results. Thus, we drop the village dummy variables and add several additional variables at the village level; meanwhile, we control for the county dummy variables. As XSBN is a Dai minority autonomous prefecture and 95% of which are a mountainous region, as shown in Table 7, we add an ethnic dummy variable and the average elevation of the village. The newly adding independent variables also consist of the distance from the village to the county center and the number of population in the village.

Table 7: Additional independent variables for robustness check

Variables	Description	Means	Std. Dev.
Dai	Ethnicity in the village (1=Dai ethnicity; 0= Other ethnicities)	0.58	0.49
Elevation	Elevation of the village (meters above sea level)	756.11	160.27
Remoteness	Distance from the village to the county center (km)	79.31	46.54
Population	Number of population in the village	82.93	45.71
County: Menghai	(1= Menghai; 0= Otherwise)	0.14	0.34
Jinghong	(1= Jinghong; 0= Otherwise)	0.45	0.50
Mengla	(1= Mengla; 0= Otherwise)	0.41	0.49
Observations		612	

Source: Authors' survey

Table 8: Robustness check for the empirical models

	Probit		Bivariate probit				Multivariate probit (Decrease by 50%)						Multivariate probit (Increase by 50%)					
			Decrease by 50%		Increase by 50%		Rent out		Rubber -crops		Reduce input		Rent in		Crops -rubber		Increase input	
Price (1=Increase by 50%;	0.544	***																
0=Decrease by 50%)	(0.076)																	
Path dependence	-0.018	***	-0.021	***	-0.016	**	-0.015	**	-0.008		0.001		-0.013	*	-0.012	*	-0.011	*
	(0.005)		(0.007)		(0.008)		(0.008)		(0.007)		(0.007)		(0.007)		(0.007)		(0.007)	
Sunk cost	-0.167	***	-0.174	**	-0.165	**	-0.076		-0.176	*	-0.218	**	-0.035		-0.040		-0.167	**
	(0.050)		(0.073)		(0.070)		(0.091)		(0.094)		(0.098)		(0.075)		(0.085)		(0.085)	
Age of respondent	-0.006		-0.007		-0.006		-0.008		-0.006		-0.012	**	-0.001		0.001		-0.008	
	(0.004)		(0.005)		(0.006)		(0.005)		(0.005)		(0.005)		(0.005)		(0.005)		(0.005)	
Education of respondent	0.010		0.005		0.016		0.000		-0.001		-0.017		0.020		0.011		0.007	
	(0.012)		(0.016)		(0.018)		(0.017)		(0.016)		(0.015)		(0.016)		(0.016)		(0.016)	
Household size	0.016		0.060		-0.038		0.030		0.041		0.053		0.024		-0.034		-0.022	
	(0.028)		(0.038)		(0.041)		(0.040)		(0.038)		(0.037)		(0.038)		(0.039)		(0.037)	
Household wealth	0.001	**	0.001		0.001		0.001		0.001	**	0.000		0.002	***	0.002	**	0.001	
	(0.000)		(0.001)		(0.001)		(0.001)		(0.001)		(0.001)		(0.001)		(0.001)		(0.001)	
Planting area of other crops	0.011		-0.054		0.061		0.155		-0.111		0.147		-0.071		0.017		0.002	
	(0.175)		(0.235)		(0.209)		(0.233)		(0.276)		(0.246)		(0.232)		(0.235)		(0.217)	
Dai	**0.298**	***	**0.208**	*	**0.392**	***	0.039		0.101		**0.321**	***	**0.294**	**	**0.290**	**	**0.292**	**
	(0.084)		(0.116)		(0.123)		(0.122)		(0.115)		(0.115)		(0.116)		(0.118)		(0.114)	
Elevation	**0.001**	*	0.000		**0.001**	*	0.000		0.000		**0.001**	**	0.000		0.001		**0.001**	*
	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	
Remoteness	**-0.003**	***	-0.002		**-0.004**	***	0.000		0.002		**-0.002**	*	-0.001		-0.001		**-0.004**	**
	(0.001)		(0.001)		(0.001)		(0.001)		(0.001)		(0.001)		(0.001)		(0.001)		(0.001)	
Population	0.002	*	0.001		0.003	*	0.001		0.001		-0.002	*	0.002		0.001		0.000	
	(0.001)		(0.001)		(0.001)		(0.001)		(0.001)		(0.001)		(0.001)		(0.001)		(0.001)	
County	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
Cons_	-0.002		0.162		0.423		0.254		-0.584		-0.549		-0.494		-0.771		0.387	
	(0.373)		(0.509)		(0.563)		(0.521)		(0.508)		(0.504)		(0.509)		(0.518)		(0.500)	
Obs.	1224		612						612						612			
Wald test of rho=0					66.720	***			404.872	***					323.069	***		
Wald chi2	105.25	***			58.110	***			66.76	***					60.6	***		

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

Table 8 reports the re-estimation results for the equation (9) and the system equations (10), (11) and (12) by further controlling for the additional independent variables in Table 7. The major results about the asymmetric response to price change and the impacts of sunk cost and path dependency on the response behaviors are consistent with the empirical results in Tables (3), (4) and (6), confirming the stability of the main findings in this study.

Furthermore, there are several interesting findings in Table 8. Compared to the other ethnicities, the Dai ethnic farmers are more likely to adjust their production behaviors in the response to the change of rubber price. The probability of adjusting productive productions in the response to the hypothetical change of rubber price is positively associated with the elevation of the village. In contrast, the remoteness is negatively correlated with the likelihood to adjust productive behavior in the response to the expected change of rubber price.

6. Concluding remarks

The supply response for the agricultural products with long production period, such as trees, perennial crops, dairy and animal products to the price volatility is complicated and generally analyzed using time series data in previous studies. Based on a simple choice experiment of smallholder rubber farmers in XSBN, this study investigates the asymmetric response of farmers to the volatility of rubber price and examine the impacts of the sunk cost and path dependency of rubber farming of their response behaviors. While the sunk cost and path dependency of rubber farming are negatively correlated with the likelihood to adjust their productive behaviors in the response to the two hypothetical changes in rubber price, the differences in the impacts of sunk cost and path dependency on the response probabilities can explain the observed asymmetric response to some extent.

This study not only complements the studies on the supply response for rubber (Dowling 1979; Hartley et al., 1987) but also have important implications for a better understanding of the periodic oversupply and the price risk for the agricultural products with

long production period. The asymmetric response of farmers to the volatility of rubber price, i.e. a higher probability of adjusting agricultural production behavior when rubber price is expected to increase than that when rubber price is expected to decline, provide a possible reason for the periodic oversupply of rubber. Furthermore, while generally a relatively long production experience and large scale of intensified agriculture can contribute to a efficient production, this study reveals that higher sunk cost and longer path dependence on rubber farming may hinder the response behaviors of smallholder farmers to cope with the risk of rubber price fluctuations.

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Appendix

Table A.1: Pairwise correlations across all regressors

Variables	Path	Sunk	Age	Education	HHsize	Wealth	Area
Path	1						
Sunk	-0.0644	1					
Age	0.0323	-0.045	1				
Education	-0.0488	0.1022**	-0.346***	1			
HHsize	0.1776***	-0.0734*	0.1801***	-0.0953*	1		
Wealth	0.1797***	0.0879**	-0.0088	0.0129	-0.1545***	1	
Area	-0.3071***	0.1561***	-0.0216	0.0943*	-0.0899**	-0.0751*	1

Source: Authors' calculation

Table A2: Variance inflation factors (VIFs)

Variable	VIF	1/VIF
Path dependence	1.18	0.848449
Age of respondent	1.17	0.857327
Education of respondent	1.15	0.866631
Planting area of other crops	1.14	0.880047
Household size	1.11	0.900271
Household wealth	1.08	0.921916
Sunk cost	1.05	0.956238
Mean VIFs	1.13	

Source: Authors' calculation