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Farm Household Pluriactivity, Factor Inputs, and Crop Structure Adjustment: Evidence from Sichuan Province, China

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Abstract

Farm household pluriactivity has become increasingly prevalent in China; however, its influence on crop structure remains insufficiently explored. This study examines the impact of farm household pluriactivity on crop structure in China, focusing on factor input mechanisms. Based on survey data from 473 farm households in Sichuan Province, this study employs ordinary least squares (OLS), two-stage least squares (2SLS), and mediation analyses to systematically assess the impact of pluriactivity on crop structure through factor input mechanisms. The analysis reveals three key findings. First, rather than reducing the grain planting area, an increase in part-time farming is associated with a significant rise in the proportion of grain cultivation. Second, factor inputs partially mediate this relationship: while pluriactivity tends to reduce staple crop cultivation through mechanisms such as cultivated land transfer-out, land abandonment, and increased non-agricultural labor input, it simultaneously promotes staple crop expansion via enhanced agricultural technical services. Third, heterogeneity tests indicate that the positive effect of pluriactivity on staple crop cultivation is especially pronounced among households in hilly areas and those that have adopted agricultural insurance. These findings provide valuable policy insights for fostering sustainable agricultural transitions and enhancing food security in developing regions.

Keywords: pluriactivity; factor inputs; staple crop cultivation behavior; topographical heterogeneity

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1. Introduction

China's position as the world's most populous nation necessitates robust food security systems to ensure social stability and citizen welfare. Rapid socioeconomic development, coupled with institutional reforms—such as the deregulation of the household registration system—has spurred an optimal reallocation of labor between the agricultural and non-agricultural sectors [1,2]. Because income derived solely from agricultural operations fails to secure an adequate standard of living for an individual [3,4], many younger, better-educated family members seek salaried employment in non-agricultural sectors [5], while other members remain in rural areas to continue farming. The phenomenon of farm households engaging in both agricultural and other industrial production and business activities at the same time is referred to as the pluriactivity of farm households. This pluriactivity pattern arises from two key mechanisms: endogenous constraints due to insufficient farm

income and exogenous incentives driven by rising non-agricultural returns, both of which represent a pivotal aspect of rural social differentiation [6,7]. As the primary stakeholders in agriculture, rural households' operational transformations fundamentally affect grain production and food security [8]. As farm household pluriactivity becomes increasingly prevalent in China, it is crucial to understand its effects on crop structure to inform sustainable agricultural policies and enhance food security. These dynamics underscore the critical need to investigate the structural impacts of pluriactivity on crop composition.

The behavioral theory of agricultural households posits that farm operators, as rational economic agents, optimize household resource allocation through systematic industrial selection to maximize returns [9,10]. These rational decisions drive the dynamic reconfiguration of resource endowments, thereby reshaping agricultural production modalities [11]. Within this framework, pluriactivity can be considered a strategy for optimizing resource use in farm households, as it allows them to diversify their income sources and mitigate risks, although the extent of optimization may vary depending on individual circumstances and constraints. Two groups of factors can influence pluriactivity. Endogenous factors—including imperatives for income augmentation, pressures to absorb surplus labor, and familial operational characteristics—compel households to adopt pluriactivity strategies when confronted with suboptimal agricultural profitability [12]. Exogenous factors, such as advancements in agricultural productivity and reduced labor intensity in crop cultivation, further propel workforce migration toward non-agricultural sectors [13,14]. Contemporary scholarship also highlights synergistic interactions among these factors: agricultural seasonality and technological innovations jointly extend the duration of pluriactivity [15–17], while surplus labor facilitates non-agricultural occupational transitions, collectively catalyzing agrarian–non-agrarian labor reallocation.

Scholarly investigations have produced divergent conclusions regarding pluriactivity's agricultural impacts. Proponents demonstrate that pluriactivity accelerates cultivated land transfer [18–20], increases technological adoption rates [21], and enhances labor productivity [22]. Although pluriactivity raises cultivation opportunity costs, farm households systematically mitigate these constraints by adopting mechanization outsourcing services [23,24]. Concurrently, labor migration further prompts households to shift cultivation from labor-intensive crops to land-intensive crops, thereby increasing the staple crop cultivation ratio [25]. In contrast, critics emphasize pluriactivity's disruptive consequences, arguing that it disperses the essential labor and capital inputs required for agricultural production [26] and potentially leads to cultivated land abandonment [27]. This phenomenon exacerbates extensive farming practices and reduces overall agricultural efficiency [28,29]. Emerging evidence identifies threshold effects in these dynamics, where non-agricultural labor participation below median levels enhance the staple crop cultivation ratio, whereas exceeding these thresholds inversely diminishes it [30]. Over time, initial productivity declines from labor displacement transition into sustained gains driven by non-agricultural income-induced technological modernization and capital intensification, ultimately fostering sectoral productivity resurgence and value chain integration [31].

The existing scholarship offers multi-perspective references but predominantly examines agricultural production through frameworks of non-agricultural employment or labor migration frameworks [32,33], offering limited empirical focus on pluriactivity's direct impacts. Although conceptual linkages exist between farm household pluriactivity and agricultural labor migration, critical distinctions emerge in their analytical units: pluriactivity is analyzed at the household level, whereas labor migration is primarily examined at the individual level. This study adopts farm households as the research unit to investigate their impacts on staple crop production—a topic of both theoretical and practical significance. Prior research has largely relied on provincial panel data or nationwide microdata to assess

the effects of labor shortages on grain production [34], while studies focusing on major grain-producing regions remain scarce. As a key staple crop cultivation base, Sichuan Province has experienced sustained labor outmigration. Its predominantly mountainous and hilly terrain poses significant challenges to large-scale mechanization and intensive farming operations. Survey data from Sichuan were employed to enhance understanding of how farm household pluriactivity affects staple crop cultivation. Current approaches often measure pluriactivity using single indicators—such as non-agricultural employment duration or the number of participants—which fail to fully capture labor allocation patterns. To address this limitation, a multidimensional framework was developed, integrating the temporal dimension, spatial distribution, intensity of pluriactivity, and employment continuity. This comprehensive approach provides new insights into labor reallocation mechanisms [35].

Building on this analytical foundation, this study adopts a factor-input theoretical framework. Survey data were collected from 473 farm households in Sichuan Province—a nationally strategic staple crop production base in China. The aim of this study is to investigate the impact of farm household pluriactivity on crop structure in China, with a particular focus on the underlying mechanisms through which factor inputs influence this relationship. Given the increasing prevalence of pluriactivity and its potential implications for agricultural sustainability and food security, it is crucial to understand how engaging in multiple economic activities affects the allocation of resources and the structure of crop production. In this study, we aim to address the following important issues. First, we assess the extent to which pluriactivity influences the proportion of different crops in farm households. Second, we identify the specific factor inputs that mediate the relationship between pluriactivity and crop structure. Third, we examine the heterogeneity of these effects across different regions and types of farm households.

2. Theoretical Analysis and Hypotheses

2.1. Direct Impact of Farm Household Pluriactivity on Staple Crop Cultivation Ratio

According to household labor allocation theory, family members strategically specialize based on their comparative advantages to maximize overall household economic returns [3]. In rural areas characterized by accessible labor markets, low barriers to non-agricultural employment, and relatively modest returns from staple crop cultivation, rural laborers—particularly young adults—are increasingly choosing non-agricultural jobs [22]. This shift results in agricultural labor shortages that fundamentally influence crop structure adjustment decisions [36]. When the reduced availability of agricultural labor due to pluriactivity constrains planting options, such limitations can be offset through mechanization or the outsourcing of agricultural technical services [37]. As pluriactivity intensifies, households tend to prioritize expanding the cultivation of staple crops that are amenable to mechanization, while simultaneously reducing the production of labor-intensive cash crops [38]. Moreover, the part-time employment of farmers raises the opportunity cost of their participation in agricultural production, as compared to their preference for food crops to minimize the cost of farming and thus increase the efficiency of production [39]. Based on the foregoing analysis, we propose the following hypothesis:

H1. *Farm household pluriactivity directly increases the staple crop cultivation ratio.*

2.2. The Mediating Role of Factor Inputs Between Farm Household Pluriactivity and Staple Crop Cultivation Ratio

2.2.1. The Mediating Role of Land Inputs

Engagement in intensive pluriactivity among farm households often leads to a higher proportion of non-agricultural income, diminishing reliance on agricultural earnings and influencing land-use decisions [40]. On one hand, transferring cultivated land can mitigate issues like extensive farming or abandonment due to labor shortages, thereby reducing resource wastage. Additionally, it can provide supplementary household income and improves family economic returns. On the other hand, pluriactive households may exhibit decreased attachment to land, especially parcels that are remote, have poor soil fertility, or lack adequate irrigation, making them more susceptible to being left idle or abandoned [41]. When non-agricultural income sufficiently supports household livelihoods and agricultural production yields relatively low profitability, farmers might withdraw from farming activities, leading to land abandonment [42]. Time and energy constrains, coupled with limited access to comprehensive agricultural technical services, can further hinder timely field management and farming operations, exacerbating abandonment [43]. Both land transfer and abandonment directly reduce the area allocated to staple crop cultivation. Moreover, prolonged abandonment can result in soil degradation, weed infestation, and pest proliferation, increasing the difficulty of recultivation and ultimately compromising the sustainability of grain production [44]. Based on the above analysis, the following hypotheses are proposed:

H2. *Farm household pluriactivity indirectly reduces the staple crop cultivation ratio through land input contraction.*

H2a. *Farm household pluriactivity indirectly reduces the staple crop cultivation ratio through cultivated land transfer-out.*

H2b. *Farm household pluriactivity indirectly decreases the staple crop cultivation ratio through cultivated land abandonment.*

2.2.2. The Mediating Role of Capital Inputs

Pluriactivity brings more income to households; at the same time, the temporal constraints imposed by pluriactivity drive a focus on efficiency-enhancing capital intensification [45]. In response to reduced labor availability, households adopt a series of strategies, such as investing in agricultural machinery, synthetic fertilizers, biocides, and certified seeds to increase grain yield and quality, boost the income from grain cultivation, and thus prompt farmers to expand the area of grain planting [46]. Moreover, capital inputs facilitate the strategic modernization of agricultural infrastructure, particularly through the upgrading of irrigation and drainage systems. Good farmland infrastructure helps to improve the conditions for grain cultivation and enhance the land's productivity, which in turn increases the staple crop cultivation ratio [47]. This mechanistic analysis supports the following hypothesis:

H3. *Farm household pluriactivity indirectly increases the staple crop cultivation ratio through the intensification of capital inputs.*

2.2.3. The Mediating Role of Technical Inputs

Specialized agricultural technical services play a pivotal role in enabling farm households to access advanced cultivation techniques and integrated pest management protocols [48]. The dual-occupation pattern characteristic of pluriactivity creates competing labor demands between the agricultural and non-agricultural sectors, resulting in operational fragmentation that can undermine overall productivity [49]. The emergence of new agricultural service entities has enhanced rural communities' capacity to provide technical services, thereby facilitating the adoption of modern solutions by pluriactive households [50]. This adoption helps to reduce machinery acquisition costs, optimize labor allocation, and alleviate constraints caused by workforce shortages and resource limitations, collectively enhancing production efficiency. Moreover, technical modernization further streamlines production processes through mechanization substitution. Figure 1 shows the theoretical framework and mechanism of this research. This mechanistic pathway underpins the following hypothesis:

H4. *Farm household pluriactivity indirectly increases the staple crop cultivation ratio through the adoption of enhanced technical services.*

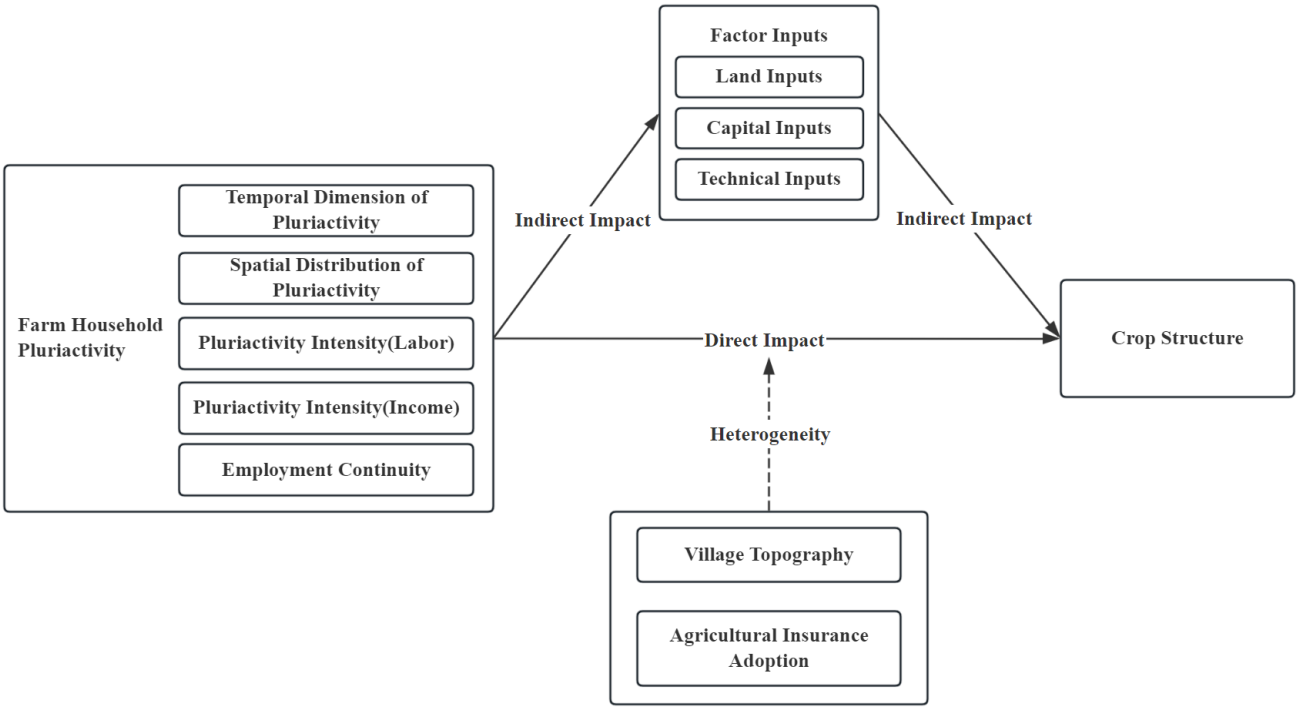


Figure 1. Theoretical analysis framework.

3. Methodology

3.1. Data Source

The dataset is derived from structured questionnaires administered in October 2023 in three major grain-producing areas of Sichuan Province: Qionglai City, Luxian County, and Nanjiang County. The survey collected comprehensive data on households engaged in staple crop farming, including individual and household characteristics, land endowment, production patterns, and village-level contextual factors. A three-stage stratified random sampling protocol was employed. First, all 183 county-level administrative units in Sichuan Province were stratified into three clusters based on composite indices of economic development, agricultural output, and labor migration patterns; one county was then randomly selected from each cluster. Subsequently, within each selected county, townships were

further stratified according to economic development gradients and proximity to administrative centers, and three villages were randomly chosen from each township stratum, resulting in twenty-seven sample villages. Finally, systematic random sampling of 20 farm households per village, based on official registries, yielded 473 valid farm household samples following rigorous data validation.

3.2. Model Setting and Variable Selection

3.2.1. Modeling

(1) Baseline regression model

Given the continuous nature of the staple crop cultivation ratio variable, the following econometric specification was adopted to examine the impact of pluriactivity on staple crop cultivation ratio in Sichuan Province:

$$Y_i = \alpha + \theta D_i + \beta X_i + \varepsilon_i \quad (1)$$

In Model (1), Y_i denotes the dependent variable measuring the farm household's staple crop cultivation ratio. X_i captures the pluriactivity behavior of the ith household, while D_i represents control variables at the household-head, family, and village levels. α is the constant term, and ε stands for the stochastic disturbance term.

(2) 2SLS model

To address potential endogeneity arising from measurement errors that may cause inconsistent parameter estimates, Heckman's instrumental variable methodology was applied through instrument selection. The two-stage least squares (2SLS) model was used for equation estimation, as specified below:

$$x = \rho + \delta z + \lambda T + \mu \quad (2)$$

$$y = \tau + \varphi \hat{x} + \omega z + \sigma \quad (3)$$

where T is the instrumental variable that is strongly correlated with the endogenous regressor x but uncorrelated with the disturbance term. In this study, z is measured as the average pluriactivity level among other sample households within the same village. The term $\hat{x}$ denotes the fitted values from the first-stage regression of x on T and the control variables, where ρ and τ are constant terms, and μ and σ represent disturbance terms.

(3) Mediation effects model

The mediating mechanisms of factor inputs between pluriactivity and staple crop cultivation ratio were examined using stepwise regression. The econometric framework was operationalized as follows:

$$Y_i = \alpha_0 + \alpha_1 X_i + u_{1i} \quad (4)$$

$$M_i = \gamma_0 + \gamma_1 X_i + u_{2i} \quad (5)$$

$$Y_i = \eta_0 + \eta_1 X_i + \eta_2 M_i + u_{3i} \quad (6)$$

where Y_i denotes staple crop cultivation ratio as the dependent variable, X_i represents farm households' pluriactivity behavior as the independent variable, and M_i signifies factor inputs. α_1 captures the total effect of pluriactivity on staple crop cultivation ratio. γ_1 measures the effect of pluriactivity behavior on factor inputs allocation, while η_1 indicates the direct effect of pluriactivity on staple crop cultivation ratio after controlling for the mediating role of factor inputs. η_2 quantifies the effect of factor inputs on staple crop cultivation ratio. The indirect effect is quantified by $\gamma_1\eta_2$, with the total effect expressed as

$\alpha_1 = \gamma_1\eta_2 + \eta_1$. The terms α_0, γ_0, and η_0 denote constant terms, whereas u_{1i}, u_{2i}, and u_{3i} represent disturbance terms.

3.2.2. Selection of Variables

(1) Explained variables

This study measures agricultural crop structure through the staple crop cultivation ratio, which represents the percentage of a household's total cultivated area allocated to rice, wheat, and maize production [51].

(2) Core explanatory variables

Previous studies employed principal component analysis to construct macro-level sectoral performance indicators [52]. In contrast, this study shifts the focus to micro-level household behavior. We conceptualize farm household pluriactivity as the key independent variable through four dimensions: the temporal dimension of pluriactivity, spatial distribution of pluriactivity, pluriactivity intensity, and employment continuity [53,54]. The temporal dimension of pluriactivity was quantified as the proportion of time spent on non-agricultural employment to total household disposable time. The spatial distribution of pluriactivity was measured by the proportion of migrant non-agricultural workers relative to the total family labor force. The pluriactivity intensity was determined by two components: the percentage of pluriactive workers in the total workforce and the percentage of non-agricultural income in total household income. The employment continuity was evaluated by the proportion of pluriactive workers with steady non-agricultural employment among all pluriactive workers [55].

(3) Mediating variables

While existing studies have quantified the aggregate TFP effects of resource misallocation, this study extends the understanding by examining its microeconomic foundations—specifically, how farm households allocate production factors under pluriactivity. We develop and test a mediation framework to analyze how pluriactivity influences staple crop cultivation patterns through land, capital, and technical inputs [56]. The land inputs were captured by cultivated land transfer-out and abandonment behaviors, quantified by the corresponding area measurements. The capital inputs were operationalized through per-mu expenditures on agricultural capital inputs. The technical inputs were quantified by the number of agricultural technical services adopted in grain production, specifically including mechanized plowing, mechanized sowing, mechanized harvesting, irrigation services, plant protection services, and cultivation technique advisory services.

(4) Control variables

To address potential omitted variable bias, this study selects control variables from three dimensions based on the existing literature: individual characteristics, household characteristics, and village characteristics. The individual characteristics of the household head include gender, age, education level, and cadre status. The household operational characteristics comprise participation in agricultural insurance, the rate of technical training, and membership of professional associations or cooperatives. The village characteristics are measured by the internet access rate, the ratio of paved roads, and village topography.

As shown in Table 1, 90.3% of surveyed households had male household heads. The average household head age was 58.03 years, and their education levels were primarily lower-secondary-level. Among the households surveyed, 7% of household heads served as village cadres. Regarding household characteristics, 33.4% of households purchased agricultural insurance; however, only 6.1% of laborers received technical training and 6.1% were joined professional organizations.

Table 1. Variable description and descriptive statistics.

Variable Name	Variable Definition	Mean	St. Dev.
Staple Crop Cultivation Ratio	The ratio of staple crop cultivation area (rice, wheat, maize)	0.485	0.357
Temporal Dimension of Pluriactivity	Ratio of household labor time devoted to non-agricultural employment	0.538	0.378
Spatial Distribution of Pluriactivity	Percentage of pluriactive labor working locally	0.462	0.454
Pluriactivity Intensity	Number of pluriactive workers/total labor force	0.493	0.363
	Pluriactive income/total household income	0.604	0.410
Employment Continuity	Percentage of non-agricultural workers with formal contracts	0.389	0.445
Gender Of Household Head	Male = 1, female = 0	0.903	0.297
Age Of Household Head	Actual age in years	58.030	10.398
Educational Attainment	No schooling = 1, primary = 2, junior high = 3, senior high = 4, college+ = 5	2.632	0.813
Cadre Status	Village cadre= 1, non-cadre = 0	0.070	0.255
Agricultural Insurance Adoption	Insured = 1, non-insured = 0	0.334	0.472
Technical Training Participation	Percentage of household members receiving agri-training	0.241	0.655
Professional Organization Membership	Member = 1, non-member = 0	0.061	0.240
Village Internet Penetration	Percentage of households with internet access	0.899	0.155
Village Road Pavement Coverage	Percentage of paved roads in village	0.848	0.129
Village Topography	Mountainous = 1, hilly = 2, plain = 3	1.624	0.678
Cultivated Land Transfer-Out	Transferred-out cultivated land area (acres)	0.689	1.613
Cultivated Land Abandonment	Abandoned cultivated land area (acres)	0.339	1.376
Capital Inputs	Log of production input costs per acre	6.448	2.898
Technical Services Adoption	Count of adopted services (mechanized plowing/sowing/harvesting, irrigation, plant protection, cultivation technique advisory)	0.395	0.971

4. Results

4.1. Baseline Regression Analysis

Using STATA 17.0, baseline regression analysis was conducted to examine the impact of farm household pluriactivity on staple crop cultivation ratio. The staple crop cultivation ratio served as the dependent variable, while we selected temporal dimension of pluriactivity, spatial distribution of pluriactivity, pluriactivity intensity (labor), pluriactivity

intensity (income), and employment continuity as independent variables. Table 2 presents the complete regression results.

Table 2. Results of the regression analysis.

Variables	(1)	(2)	(3)	(4)	(5)
	Crop Structure				
Temporal Dimension of Pluriactivity	0.105 **				
	(2.457)				
Spatial Distribution of Pluriactivity		0.077 **			
		(2.147)			
Pluriactivity Intensity (Labor)			0.102 **		
			(2.349)		
Pluriactivity Intensity (Income)				0.111 ***	
				(2.829)	
Employment Continuity					0.176 ***
					(5.159)
Gender of Household Head	0.020	0.015	0.022	0.012	0.005
	(0.382)	(0.293)	(0.425)	(0.225)	(0.093)
Age of Household Head	0.003 **	0.003 **	0.003 **	0.004 **	0.003 **
	(2.139)	(2.078)	(1.975)	(2.297)	(2.012)
Educational Attainment	−0.011	−0.014	−0.011	−0.007	−0.004
	(−0.499)	(−0.657)	(−0.509)	(−0.355)	(−0.175)
Cadre Status	−0.131 **	−0.128 **	−0.131 **	−0.133 **	−0.148 **
	(−2.052)	(−1.999)	(−2.051)	(−2.086)	(−2.369)
Agricultural Insurance Adoption	0.196 ***	0.196 ***	0.197 ***	0.204 ***	0.183 ***
	(5.816)	(5.807)	(5.842)	(6.014)	(5.558)
Technical Training Participation	−0.004	0.001	−0.001	−0.003	−0.006
	(−0.145)	(0.021)	(−0.035)	(−0.121)	(−0.242)
Professional Organization Membership	−0.077	−0.091	−0.075	−0.068	−0.085
	(−1.143)	(−1.344)	(−1.120)	(−1.014)	(−1.299)
Village Internet Penetration	0.398 ***	0.424 ***	0.400 ***	0.388 ***	0.394 ***
	(3.748)	(4.019)	(3.773)	(3.659)	(3.807)
Village Road Pavement Coverage	−0.052	−0.015	−0.028	−0.040	−0.056
	(−0.383)	(−0.112)	(−0.208)	(−0.299)	(−0.425)
Village Topography	−0.078 ***	−0.084 ***	−0.076 ***	−0.074 ***	−0.081 ***
	(−2.986)	(−3.184)	(−2.901)	(−2.825)	(−3.184)
R^2	0.152	0.149	0.151	0.155	0.188
Observations	473	473	473	473	473

Note: T value in parentheses; ** $p < 0.05$, *** $p < 0.01$.

The regression results indicate statistically significant positive effects of farm household pluriactivity on staple crop cultivation ratio across multiple dimensions: temporal dimension of pluriactivity demonstrates a significant positive impact at the 5% level, with each unit increase elevating the staple crop cultivation ratio by 10.5%. Spatial distribution of pluriactivity shows a positive association at the 5% significance level, where a one-unit increment corresponds to a 7.7% increase in cultivation ratio. Pluriactivity intensity (labor) exhibits a positive effect at the 5% level, indicating a 10.2% rise in cultivation ratio per unit increase. Pluriactivity intensity (income) reveals a stronger positive relationship at the 1% significance level, with each unit increase resulting in an 11.11% higher cultivation ratio. Employment continuity displays the most pronounced positive effect at the 1% level, meaning that each unit increase in stable pluriactivity employment ratio augments the cultivation ratio by 17.6%.

Among the control variables, the age of household head variable shows a positive and significant effect on the dependent variable in all models, which are statistically significant

at the 5% level, suggesting that older household heads may demonstrate stronger preferences for domestic agricultural production. The cadre status coefficient is negative and significant at the 5% level, likely because cadres assume greater administrative responsibilities that limit their available time and energy for agricultural activities. The agricultural insurance adoption variable is positive and significant at the 1% level; given agricultural production's vulnerability to natural disasters, insurance coverage helps mitigate disaster-induced poverty risks, and consequently improves farmers' cultivation incentives. Village internet accessibility shows a significant positive correlation with staple crop cultivation ratio at the 1% level, as farmers can efficiently acquire advanced cultivation techniques through various digital channels, including online agricultural courses, technical forums, and expert lecture videos. Village topography is negative and significant at the 1% level. Village terrain flatness demonstrates a potential negative influence on staple crop cultivation ratio—while flat topography facilitates both staple and cash crop production, market incentives may prompt farmers to prioritize higher-value cash crops over staple crop cultivation.

4.2. Robustness Tests

To ensure the robustness of our findings and address potential estimation biases from unobserved factors, robustness checks were conducted through two approaches: (1) the OLS model was replaced with a Tobit model, and (2) the original independent variable was replaced with a pluriactivity decision dummy (1 for pluriactivity engagement, 0 otherwise). As presented in Table 3, the results demonstrate that increased pluriactivity has a significant positive effect on staple crop cultivation ratio, confirming the robustness of our findings.

Table 3. Robustness test.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Crop Structure					
Temporal Dimension of Pluriactivity	0.105 **					
	(2.489)					
Spatial Distribution of Pluriactivity		0.077 **				
		(2.175)				
Pluriactivity Intensity (Labor)			0.102 **			
			(2.379)			
Pluriactivity Intensity (Income)				0.111 ***		
				(2.865)		
Employment Continuity					0.176 ***	
					(5.225)	
Pluriactivity Decision						0.133 ***
						(3.561)
Control Variable	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
R^2	0.212	0.208	0.211	0.217	0.268	0.164
Observations	473	473	473	473	473	473

Note: T value in parentheses; ** $p < 0.05$, *** $p < 0.01$.

4.3. Endogenous Treatment

To mitigate potential endogeneity issues, Heckman's instrumental variable approach was employed, utilizing a 2SLS framework. Following established instrumental variable selection principles as documented in prior research [6], we employed the average pluriactivity level among other sample households within the same village as our instrumental variable. This variable satisfies both the relevance condition, through its strong correlation with individual household pluriactivity levels, and the exogeneity condition, by not directly affecting individual household cultivation decisions.

Table 4 presents the instrumental variable estimation results. The first-stage regression produces F-statistics that all exceed the threshold value of 10, demonstrating the instrument's strength. The second-stage results reveal that all instrumental variables surpass the critical value of 16.38 at the 10% significance level, effectively eliminating concerns about weak instruments. Notably, the instrumental variable estimates show substantial agreement with the benchmark regression results, thereby validating our core findings.

Table 4. Test of endogeneity and weak instrumental variables.

Variables	Phase I	Phase II	F-Value	Cragg–Donald Wald F Statistic	Kleibergen–Paap Rk Wald F Statistic
Temporal Dimension of Pluriactivity		0.157 ** (2.560)	406.07	340.789	406.071
Village-Level Average Temporal Dimension of Pluriactivity	0.730 *** (20.150)				
Spatial Distribution of Pluriactivity		0.238 ** (2.420)	68.14	58.564	68.140
Village-Level Average Spatial Distribution of Pluriactivity	0.737 *** (8.250)				
Pluriactivity Intensity (Labor)		0.195 ** (2.240)	73.31	109.577	132.508
Village-Level Average Pluriactivity Intensity (Labor)	0.870 *** (11.510)				
Pluriactivity Intensity (Income)		0.140 *** (4.440)	470.15	407.903	470.146
Village-Level Average Pluriactivity Intensity (Income)	0.851 *** (21.680)				
Employment Continuity		0.219 *** (2.770)	121.06	86.856	121.060
Village-Level Average Employment Continuity	0.860 *** (11.000)				
Control Variable	Controlled	Controlled	Controlled	Controlled	Controlled
Observations	473	473	473	473	473

Note: T value in parentheses; ** $p < 0.05$, *** $p < 0.01$.

4.4. Heterogeneity Analysis

The heterogeneous effects of farm household pluriactivity on staple crop cultivation ratios were examined through a two-stage classification process. First, sample villages were categorized into mountainous, hilly, and plain areas based on topographic characteristics. Subsequently, households were stratified according to agricultural insurance adoption status. The analytical results are presented in Table 5.

The analysis reveals significant topographic variation in pluriactivity's impact on the staple crop cultivation ratio. In hilly areas, the effect of pluriactivity on the staple crop cultivation ratio is most pronounced in hilly areas, where terrain constraints limit the adoption of large agricultural machinery. The coefficients for both the temporal and spatial dimensions of pluriactivity are positive and significant at the 5% level, indicating a robust positive impact. In contrast, the impact in plains areas is less significant, suggesting that the availability of cross-regional mechanized services, which are widely accessible in plains, may offset the need for pluriactivity. The coefficients in mountainous areas are also positive, but slightly lower than in hilly areas, indicating that while pluriactivity still influences crop structure, the effect is somewhat mitigated by the more severe constraints imposed by the terrain. The adoption of agricultural insurance strengthens the positive

effect of pluriactivity on the staple crop cultivation ratio. This is particularly important for pluriactive households, who typically demonstrate less intensive field management than specialized farmers, resulting in reduced resilience against natural disasters and pest infestations. Insurance coverage provides financial compensation that mitigates production risks, thereby encouraging pluriactive farmers to maintain or expand their staple crop cultivation ratio.

Table 5. Heterogeneity analysis.

Variables	Topographical			Purchase of Agricultural Insurance	
	Hilly Area	Hilly	Plains	Be	Clogged
Temporal Dimension of Pluriactivity	0.060	0.147 **	0.016	0.147 **	0.074
	(0.933)	(2.589)	(0.076)	(2.465)	(1.300)
Spatial Distribution of Pluriactivity	0.019	0.172 ***	0.163	0.063	0.064
	(0.356)	(3.435)	(1.005)	(1.107)	(1.370)
Pluriactivity Intensity (Labor)	0.062	0.176 ***	0.068	0.145 **	0.064
	(0.956)	(2.934)	(0.316)	(2.286)	(1.101)
Pluriactivity Intensity (Income)	0.042	0.163 ***	0.114	0.126 **	0.097 *
	(0.697)	(3.096)	(0.546)	(2.200)	(1.859)
Employment Continuity	0.098 *	0.249 ***	0.169	0.140 ***	0.189 ***
	(1.880)	(5.313)	(1.222)	(2.767)	(4.220)
Control Variable	Controlled	Controlled	Controlled	Controlled	Controlled
Observations	231	189	53	158	315

Note: T value in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

4.5. Mechanism Analysis

In this section, the mechanisms underlying the impact of farm household pluriactivity on staple crop cultivation ratio are investigated through mediation analysis. The results are presented in Tables 6–9.

Following the stepwise regression approach, we first established the direct effect of pluriactivity on staple crop cultivation ratio, as reported in Section 4.1. Table 6 shows that model (2) demonstrates a positive relationship between pluriactivity and cultivated land transfer-out. Models (3)–(7) indicate that cultivated land transfer-out partially mediates the relationship between pluriactivity and staple crop cultivation ratio. The analysis reveals that five pluriactivity dimensions—temporal allocation, spatial mobility, pluriactivity intensity (labor), pluriactivity intensity (income), and employment continuity—all reduce the staple crop cultivation ratio by increasing cultivated land transfer-out. These results support hypothesis H2a regarding the mediating role of land transfer in the pluriactivity–cultivation relationship.

As shown in models (3)–(7) of Table 7, cultivated land abandonment partially mediates the effect of spatial mobility on staple crop cultivation ratio. The results indicate that households with higher local pluriactive labor shares significantly reduce their staple crop cultivation ratio through increased cultivated land abandonment, thus validating hypothesis H2b. The mediating effect of cultivated land abandonment on the relationship between the duration of pluriactivity, the intensity of pluriactivity, the stability of pluriactivity, and the proportion of staple crop cultivation is not significant.

Table 6. Test of the mediating effect of cultivated land transfer between farm household pluriactivity and crop structure.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Staple Crop Cultivation Ratio	Cultivated Land Transfer-Out	Crop Structure				
Temporal Dimension of Pluriactivity	0.105 **	0.492 ***	0.114 ***				
	(2.457)	(2.603)	(2.671)				
Spatial Distribution of Pluriactivity	0.077 **	0.439 ***		0.084 **			
	(2.147)	(2.766)		(2.344)			
Pluriactivity Intensity (Labor)	0.102 **	0.749 ***			0.118 ***		
	(2.349)	(3.913)			(2.692)		
Pluriactivity Intensity (Income)	0.111 ***	0.392 **				0.118 ***	
	(2.829)	(2.236)				(3.001)	
Employment Continuity	0.176 ***	0.298 *					0.182 ***
	(5.159)	(1.919)					(5.348)
Cultivated Land Transfer-Out			−0.024 **	−0.024 **	−0.026 **	−0.024 **	−0.025 **
			(−2.280)	(−2.253)	(−2.424)	(−2.277)	(−2.486)
Control Variable	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
R^2	-	-	0.163	0.160	0.163	0.167	0.200
Observations	473	473	473	473	473	473	473

Note: T value in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7. Test of the mediating effect of cultivated land abandonment between farm household pluriactivity and crop structure.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Staple Crop Cultivation Ratio	Cultivated Land Abandonment	Crop Structure				
Temporal Dimension of Pluriactivity	0.105 **	−0.021	0.102 **				
	(2.457)	(−0.126)	(2.397)				
Spatial Distribution of Pluriactivity	0.077 **	0.369 ***		0.082 **			
	(2.147)	(2.611)		(2.266)			
Pluriactivity Intensity (Labor)	0.102 **	0.125			0.102 **		
	(2.349)	(0.719)			(2.338)		
Pluriactivity Intensity (Income)	0.111 ***	0.057				0.110 ***	
	(2.829)	(0.364)				(2.798)	
Employment Continuity	0.176 ***	−0.359 ***					0.171 ***
	(5.159)	(−2.601)					(4.971)
Cultivated Land Abandonment			−0.017	−0.021 *	−0.018	−0.018	−0.011
			(−1.480)	(−1.755)	(−1.571)	(−1.544)	(−0.915)
Control Variable	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
R^2	-	-	0.158	0.157	0.157	0.161	0.191
Observations	473	473	473	473	473	473	473

Note: T value in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The results presented in models (3)–(7) of Table 8 demonstrate that pluriactivity reduces staple crop cultivation ratio through decreased capital inputs, which contradicts hypothesis H3. By engaging in non-agricultural activities, farmers may reduce their dependence on agricultural income, thereby potentially decreasing the demand for capital investment in agriculture. Moreover, this counterintuitive finding may be attributed to the

fact that Sichuan's terrain is mostly characterized by hills and mountains, which are not suitable for large agricultural machinery. This reduces the potential scale effect that could be achieved by expanding operations, the agricultural income rate being significantly lower than the income rate from non-agricultural employment, farm households are willing to invest more capital in non-agricultural jobs, which decreases their willingness to invest in agriculture to pursue higher economic returns, thereby reducing the proportion of staple crop cultivation [45].

Table 8. Test of the mediating effect of capital inputs between farm household pluriactivity and crop structure.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Staple Crop Cultivation Ratio	**Capital Inputs**	**Crop Structure**				
Temporal Dimension of Pluriactivity	0.105 **	−0.899 ***	0.143 ***				
	(2.457)	(−2.533)	(3.596)				
Spatial Distribution of Pluriactivity	0.077 **	−1.150 ***		0.128 ***			
	(2.147)	(−3.923)		(3.790)			
Pluriactivity Intensity (Labor)	0.102 **	−1.320 ***			0.161 ***		
	(2.349)	(−3.694)			(3.939)		
Pluriactivity Intensity (Income)	0.111 ***	−0.998 ***				0.155 ***	
	(2.829)	(−3.070)				(4.218)	
Employment Continuity	0.176 ***	0.465					0.156 ***
	(5.159)	(1.065)					(4.846)
Temporal Allocation			0.045 ***	0.047 ***	0.047 ***	0.046 ***	0.041 ***
			(8.681)	(8.873)	(8.885)	(8.870)	(8.022)
Capital Inputs							
Control Variable	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
R^2	-	-	0.273	0.275	0.277	0.280	0.289
Observations	473	473	473	473	473	473	473

Note: T value in parentheses; ** $p < 0.05$, *** $p < 0.01$.

As evidenced in models (3)–(7) of Table 9, the adoption of technical services partially mediates the relationship between employment continuity and staple crop cultivation ratio. Specifically, households with more stable pluriactivity demonstrate greater technical service adoption, subsequently enhancing their staple crop cultivation ratio, thereby confirming hypothesis H4. This mediating effect likely stems from institutional support mechanisms, including the government's agricultural technology extension system and subsidy policies, which collectively safeguard farmers' technological investments. Furthermore, agricultural cooperatives and enterprises significantly contribute to technology dissemination [57,58], enabling households to sustain essential technical inputs despite pluriactivity engagement. The mediating effect of agricultural technical service adoption on the relationship between the duration of pluriactivity, the spatial distribution of pluriactivity, and the intensity of pluriactivity and the staple crop cultivation ratio is not significant.

Table 9. Test of the mediating effect of technical inputs between farm household pluriactivity and crop structure.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Staple Crop Cultivation Ratio	Technical Inputs	Crop Structure				
Temporal Dimension of Pluriactivity	0.105 **	0.056	0.100 **				
	(2.457)	(0.454)	(2.363)				
Spatial Distribution of Pluriactivity	0.077 **	−0.059		0.076 **			
	(2.147)	(−0.573)		(2.148)			
Pluriactivity Intensity (Labor)	0.102 **	−0.205			0.108 **		
	(2.349)	(−1.630)			(2.504)		
Pluriactivity Intensity (Income)	0.111 ***	0.033				0.108 ***	
	(2.829)	(0.287)				(2.750)	
Employment Continuity	0.176 ***	0.188 *					0.168 ***
	(5.159)	(1.875)					(4.928)
Technical Inputs			0.041 **	0.043 ***	0.045 ***	0.041 **	0.035 **
			(2.548)	(2.652)	(2.782)	(2.567)	(2.211)
Control Variable	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
R^2	-	-	0.165	0.164	0.167	0.169	0.198
Observations	473	473	473	473	473	473	473

Note: T value in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5. Discussion

In this paper, we provide a comprehensive empirical analysis to test and elaborate on the impact of pluriactivity on crop structure through factor input mechanisms. The following results are drawn: (1) farm household pluriactivity significantly enhances the staple crop cultivation ratio. (2) Factor input plays a partial mediating role in the impact of farm household pluriactivity on the staple crop cultivation structure. Specifically, our findings align with Ge et al. [11], who also found positive impacts of pluriactivity on agricultural outcomes. Furthermore, the study found that pluriactivity among farm households reduces the proportion of staple crop cultivation by facilitating the transfer-out of cultivated land and land abandonment, which is also supported by Hou's research [59]. However, the results regarding the mediating effect of capital investment in the impact of pluriactivity on crop structure differ from Chang's study [29]. The reasons for these differences may be because the income from non-farm sources are spent on consumption or invested in competing non-farm activities [60]. Farm household employment continuity positively affects the proportion of staple crop cultivation through increased technical input, a finding that is also supported by Hou's research [59]. In the relationship between pluriactivity and the structure of staple crops, factor inputs such as capital, labor, and technology have a certain degree of explanatory power over the outcomes, but they are not the sole determinants. These factor inputs may influence farmers' choices and adjustments to the crop structure through various pathways, yet they are also affected by other factors, such as market conditions, policy environments, and natural conditions. (3) The positive effects of farm household pluriactivity on staple crop cultivation ratio are more pronounced in hilly regions. In the plains regions, where land is contiguous and mechanization rates are high, the cost of land transfer is low. As a result, farm households engaging in pluriactivity are more inclined to grow cash crops or rent out their land, leading to a trend away from staple crop cultivation, known as non-grainization. In contrast, in mountainous areas, where the terrain is fragmented and the ecology is fragile, the marginal returns from staple crop cultivation are extremely low. Therefore, the income from pluriactivity is often used

to completely abandon agriculture. (4) Households purchasing agricultural insurance exhibit stronger positive associations between pluriactivity and staple crop cultivation ratio. Agricultural insurance mitigates financial risks associated with natural disasters or market fluctuations. With this safeguard, farmers may be more willing to maintain or increase the cultivation of staple crops, as they have some income security even under adverse conditions [61].

Compared with the existing research, this study's contributions are twofold. Theoretically, it constructs an analytical framework connecting farm household pluriactivity, factor inputs, and crop structure. Empirically, this study analyzes these relationships using Sichuan Province staple crop farming households' survey data, focusing on four analytical dimensions: temporal allocation, spatial mobility, pluriactivity intensity, and employment continuity.

Study limitations should be acknowledged. First, while this research examines the mediating role of factor inputs in the pluriactivity–crop structure relationship, other potential mechanisms require further investigation. Second, the exclusive reliance on Sichuan Province data necessitates caution in generalizing findings to other regions. Future studies should expand the geographical scope to validate the pluriactivity–crop structure relationship across diverse agricultural systems.

6. Conclusions

This study is grounded in the reality of farm household pluriactivity in China. Using OLS regression models with survey data from 473 farm households in three Sichuan Province counties (Qionglai, Luxian, and Nanjiang)—all located in major grain-producing areas—we empirically analyze how farm household pluriactivity affects crop structure, with particular focus on the mediating effects of factor inputs. First, farm household pluriactivity significantly increases staple crop cultivation ratio. Second, heterogeneity analysis reveals stronger positive effects for households in hilly regions and those purchasing agricultural insurance. Third, factor inputs demonstrate partial mediation in the pluriactivity–crop structure relationship. Based on these conclusions, this study proposes the following policy recommendations.

First, rational guidance should be provided for farm household pluriactivity. Taking into account the characteristics of local industries, enterprises should be guided to develop flexible jobs such as seasonal, temporary, and hourly jobs. Moreover, the integration of local part-time industries with food production and the development of industries related to food production should be guided. Vocational skills training for pluriactive farmers should be strengthened to enhance their employability and income levels in non-agricultural sectors. Meanwhile, skilled and experienced pluriactive laborers should be encouraged to return to staple crop production, which would help improve production techniques and management levels. Special incentive funds should be established to reward those who return to staple crop production and achieve significant economic benefits.

Second, incentives for factor inputs should be reinforced. These should include establishing a sound land transfer service platform; standardizing land transfer procedures; providing land transfer information, legal advice, and other services; and reducing land transfer costs, thereby improving land-use efficiency and increasing the staple crop cultivation ratio. The Government should continue to increase subsidies to grain farmers, including direct subsidies, agricultural subsidies, subsidies for the purchase of agricultural machinery, and subsidies for paddy rice, in order to reduce farmers' production costs and increase their incentive to grow grain. Additionally, agricultural infrastructure construction—including farmland water conservancy, road transportation, and power

communications—should be enhanced to improve production conditions, reduce the impact of natural disasters, and increase production stability.

Third, spatially differentiated governance should be implemented. Farmers in mountainous areas are given higher subsidies for grain cultivation and the purchase of agricultural machinery to reduce their costs of growing grain. At the same time, the ecological protection and restoration of mountainous areas should be strengthened, and ecological and specialty agriculture should be developed to improve the efficiency of the use of mountainous land resources and the benefits of output. This should include encouraging the development of moderate-scale operations in hilly areas and fostering new agricultural management bodies such as family farms and farmers' cooperatives. The advantages of concentrated and contiguous cultivated land in plain areas should be fully utilized at a large scale, alongside the development of food industrialization consortia to promote the integrated development of food production, processing, and marketing.

Fourth, the insurance mechanism should be optimized. The publicity and promotion of agricultural insurance should be intensified to improve farmers' awareness and acceptance. Insurance products with flexible coverage and favorable premiums can be designed for part-time farmers. At the same time, the quality of insurance services should be improved, claims procedures simplified, and the speed of claims settlement accelerated to ensure that farmers can be compensated in a timely manner after suffering disastrous losses, and to enhance their willingness to purchase agricultural insurance. The proportion of government subsidies for agricultural insurance should be increased, the cost of purchasing insurance for farmers should be reduced, and particularly importantly, certain subsidies should be given to farmers who have not purchased agricultural insurance, so as to encourage farmers to actively participate in insurance.

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