The Impact of Collective Action Dilemmas on Non-grain Production: Empirical Evidence Based on 31 Provinces in China

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Abstract. Food security is deemed "the most important issue in the country," with "non-grain production" identified as a primary concern. Central Document No. 1 consistently emphasizes the need to enhance food and significant agricultural production, yet challenges such as the collective action dilemma persist, rendering food security strategies unsustainable. For the first time, this study examines the impact of collective action dilemmas on non-grain production and aims to bridge the gap between collective action and food production at the smallholder level, proposing a new pathway toward sustainable food security. Using 2000-2020 panel data from 31 provinces in China, the initial analysis reveals the existence of collective action dilemmas concerning sustainable food security. The dilemma is notably more severe in major grain marketing areas and regions balancing grain production and marketing than primary grain-producing areas. Additionally, the study finds that non-grain utilization levels exhibit a general growth trend. Major grain-producing areas show the lowest levels of non-grain production, while major grain marketing areas show the highest, and areas balancing production and marketing fall in between; however, this pattern is evolving. Lastly, empirical evidence from the spatial error model indicates a positive spillover effect of the collective action dilemma on non-grain production. In light of these findings, the paper presents relevant policy recommendations.

Keywords: Sustainable food security; Collective action dilemmas; Non-grain production of cropland; Spatial econometric models

1 Introduction

Global food security is critically threatened by factors such as the COVID-19 pandemic, national conflicts, climate change, and natural disasters. The United Nations has designated the eradication of world hunger and malnutrition by 2030 as one of its 17 Sustainable Development Goals (SDGs). Consequently, numerous countries have incorporated food security into their national sustainable development agendas. As the largest developing nation, China faces a significant responsibility and a higher risk of

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food insecurity, making the challenge of ensuring food security particularly acute [2]. The primary challenge remains translating these abstract goals into practical actions aligned with the SDGs [3]. In recent years, sustainable food security has become an essential component of national strategies.

However, with the development of urbanization and rural factor markets, the transfer of rural labor inevitably raises concerns about Non-Grain Production (NGPs). More notably, the collective action dilemma among farmers that accompanies labor migration may incentivize large-scale NGPs. Theoretically, on the one hand, a global food security strategy as the primary means of mitigating NGPs is insufficient to create sustainable societies and limit the harms caused by limited justice [4]. The globalized food system facilitates corporate monopolies, food dumping, and exploitation by industrialized countries [1]. Food security strategies based on neoliberal approaches that emphasize "free trade" and "globalization" have widened the gap between affluent regions and the poorest marginalized countries. Additionally, the rights and power of peasants are often overlooked, and policymakers' preconceived notions of "relief rather than development" have led to inequalities and declining productivity in the food security domain [5]. On the other hand, the regional scale of the rural labor force has evolved according to market logic.

On the other hand, the regional transfer of the rural labor force driven by market logic has resulted in land and capital being concentrated in the hands of a few large farmers[6]. Meanwhile, small farmers are marginalized and driven off the land due to the triple pressures of rising production costs, low food prices, and limited individual yields[7][8][9][10]. This ongoing marginalization of small households creates a collective action dilemma at the household level, ultimately exacerbating the "nongrain" phenomenon[11].

Indeed, the transfer of rural labor promotes the development of rural factor markets[12][13], facilitating large-scale agriculture through land transfers and technological advancements. National statistics indicate that the area under cultivation and food production continues to grow normally, suggesting there has been no significant reversal in farmers' food production behavior.

Although the collective action dilemma has not yet triggered large-scale NGPs, there are clear spillovers from the provision of public goods, such as food, and collective action dilemmas. New research suggests that the negative effects of farmers' collective action dilemmas are spilling over. In recent years, food sovereignty strategies have emerged as an alternative to food security, aiming to create more sustainable and equitable food systems [14]. Adopting the food sovereignty justice paradigm by policymakers can undoubtedly help address potential problems in food production[4]. However, this approach has yet to receive sufficient attention from policymakers. One reason is that, although it empowers marginalized groups [15], the lack of concreteness in this solution leads to the dilution of benefits, preventing smallholder farmers, as marginalized groups, from uniting to form a cohesive and enforceable social force[16].

The preceding analysis suggests that a policy orientation that relies solely on market logic and price mechanisms, coupled with a lack of enforceability, may ultimately lead to outcomes that run counter to the goals of the national food security strategy [17]. If the collective action dilemma, primarily in the form of labor migration, results in a significant increase in non-grain cultivation, the risk of non-grain food insecurity in the country will also increase significantly. Therefore, how can the gap between smallholder farmers and food production be bridged to promote sustainable food security? Promoting sustainable food security through collective action may be a viable approach. As food is a public good, ensuring sustainable food security requires the participation of the entire society[18]. Thus, collective action may catalyze food security [19]. However, this aspect has not been fully explored, and there are fewer empirical studies on its solution logic. The question of how the collective action dilemma in developing countries like China affects "non-grain" and how these countries can employ collective action to mitigate the development of "non-grain" for promoting sustainable food security has yet to be addressed.

In light of this, the present paper aims to investigate the relationship between collective action dilemmas and NGPs, offering tailored policy recommendations. Beginning with an examination of the collective action dilemma within the food supply domain, this study will employ the Moran index to assess the presence of spatial spillover effects associated with NGPs. Subsequently, a spatial econometric model will be utilized to ascertain whether the collective action dilemma contributes to the emergence of "non-grain" issues. Moreover, the paper will delve into whether collective action dilemmas exert varying impacts on "non-grain" challenges across food-producing, marketing-centric, and production-marketing equilibrium regions. It is anticipated that these findings will yield fresh insights and policy directives for enhancing sustainable food security governance and the delivery of public goods services in developing nations.

This paper seeks to address the following three inquiries:

(1) Does a collective action dilemma exist in food provisioning?

(2) To what extent does the collective action dilemma exacerbate the issue of NGPs?

(3) How can collective action offer an effective framework for mitigating the proliferation of NGPs?

2 Theoretical Analysis and Hypothesis

2.1 The Impact of Collective Action Dilemmas on Ngps

Farmers encounter a collective action dilemma in food production. Olson, in his seminal work "The Logic of Collective Action," contends that due to the rational behavior of individuals and their pursuit of profit maximization within the economy, when confronted with public goods or services, individuals are inclined not to undertake actions conducive to achieving collective interests. Consequently, when a majority of individuals are motivated by the tendency to "free-riding behavior" collective action aimed at achieving common goods fails to materialize, thereby presenting a significant challenge to collective endeavors [20]. Food is considered a pure public good for several reasons. Firstly, it is non-rivalrous, meaning that one individual's food consumption does not diminish its availability to others. Sustainable food security, as defined, is inherently tied to the public interest. In this context, increasing the number of consumers does not incur additional costs, signifying a marginal cost of zero. Secondly, food is non-exclusive, meaning that its benefits extend to all members of society, and individuals can utilize or enjoy it simultaneously. However, the non-competitive and non-exclusive nature of these benefits often gives rise to participation dilemmas. Despite benefiting from sustainable food security, individuals may still have a vested interest in refraining from collective action and instead relying on the efforts of others. If "free-riding" becomes pervasive, where no individuals participate, no benefits are generated[21]. Therefore, at a theoretical level, farmers may exhibit free-riding behavior when confronted with food security as a public good, particularly concerning decisions regarding the utilization of arable land.

The collective action dilemma contributes to the emergence of NGPs for several reasons. Rooted in Olson's assertion, a crucial factor determining individuals' participation in collective action is the balance between the cost of benefiting from the collective good and the cost of participating in its provision [20]. Therefore, the primary driver motivating farmers' engagement in food production is the comparative returns associated with it. As rational economic agents, farmers aim to maximize their utility. However, when faced with insufficient incentives for food cultivation, high sunk costs and comparatively lower returns, farmers may opt for alternative agricultural practices, leading to NGPs.

Furthermore, concerning access to rights, the loss of regional farmers' food sovereignty and their inability to select primary producers and markets have compelled farmers to pursue fragmentation strategies for their livelihoods.

So, how should we break the dilemma? Previous studies seem to give us some insights[21] [22] [23] [24] [25]. In summary, collective action theory has been widely applied to public resource management, public health management, environmental management, and public safety. The theoretical logic of collective action has become a systematic and effective perspective for governing problems in the public sphere. Based on the above discussion, this paper details the logic of the impact of collective action on NTFPs in Figure 1.

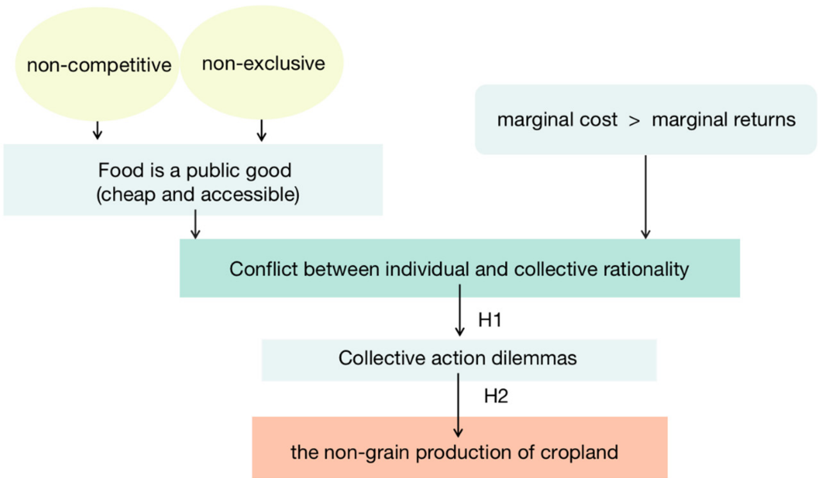

Fig. 1. Logogram of the impact of collective action on NGPs (Self-drawn by the author)

2.2 Hypothesis

Building upon the preceding analysis, this paper posits the following theoretical hypotheses:

H1: A collective action dilemma is present in the realm of food production.

H2: The collective action dilemma precipitates the issue of NGPs.

Subsequent sections of the paper will empirically examine and assess these hypotheses.

3 Data Sources and Research Methods

3.1 Data Sources

Given considerations regarding data availability, this paper focuses on 31 provinces, municipalities, and autonomous regions within China, excluding Hong Kong, Macau, and Taiwan. The dataset comprises panel data spanning 20 years (2000-2020), sourced from various publications, including the China Rural Statistical Yearbook, China Statistical Yearbook, provincial statistical yearbooks, and China Labor Statistical Yearbook. The explanatory variable under scrutiny is the collective action dilemma, while the dependent variable is the extent of NGPs across each province, city, and autonomous region. Standardization procedures are applied to mitigate issues of data heteroskedasticity and account for variations in data volume across different sources. Stata18 software is employed for the statistical analysis conducted in this study.

3.2 Variable Selection

3.2.1 Explained Variable

The dependent variable in this study is the extent of regional "non-grain" cultivation. Due to data availability and credibility considerations, this study assesses the level of "non-grain" cultivation solely from the perspective of cultivation structure. Consistent with existing literature, the proportion of cultivated land allocated to non-grain crops relative to the total cultivated area is utilized to quantify the extent of "non-grain" cultivation [26]. The specific calculation formula is as follows:

$$Y = 1 - \frac{G_a}{S_a} \tag{1}$$

In the above formula, " Sa " denotes the total sown area of crops, "Ga" denotes the sown area of food crops, and " Y " is the value of the measured level of " nongrain " of arable land.

3.2.2 Core Explanatory Variables

The central explanatory variable in this study is the collective action dilemma faced by farmers in food production, specifically, the occurrence of free-riding behavior. Wang et al. (2022) demonstrated the negative impact of labor outflow on the collective action capacity of rural communities[27][28], whereby labor outflow leads to a decline in the farm-to-labor ratio. To standardize data and enhance measurability, this paper quantifies the degree of the collective action dilemma based on the extent of decline in the capital-labor ratio [29]. The specific measurement formula is as follows:

$$I = \frac{L^A}{L} \tag{2}$$

$$X = I_t - I_{t+1} \tag{3}$$

In the above formula, "LA" denotes the number of people in the primary sector, "L " denotes the number of people engaged in agricultural production, " I" denotes the farm-to-labor ratio, and "X" is the value of the measured level of collective action distress.

3.2.3 Control Variable

Drawing on existing literature, this study has chosen several covariates to control for potential confounding factors. These include living variables such as the proportion of output value derived from the primary industry, the urban-rural income gap[30], and the proportion of government financial expenditure allocated to agriculture[31]. Additionally, production-related variables such as the total power of agricultural machinery and the cropland replanting index have been selected[32][33]. Finally, ecological variables such as the effective irrigated area have also been included as control variables [34](Table 1).

Table 1. Explanation of control variable indicators

Impact factors	Impact classification	Indicator interpretation
Life variables	a1: The proportion of primary industry output value	The ratio of the total amount of agricultural, forestry, animal husbandry, and fishery products to the regional gross domestic product (%) reflects the total scale of regional agricultural production.
	a2: Income gap between urban and rural areas	The ratio of disposable income of rural residents to disposable income of urban residents (%) (the ratio of net income of rural residents to net income of urban residents) reflects the urban-rural gap in the region.
	a3: Proportion of government expenditure on agriculture	The ratio of the total amount of fiscal support for agriculture (forestry, water) funds to GDP (%) reflects the degree of government attention.
Production variables	a4: Total power of agricultural machinery	The higher the total power of agricultural machinery, the higher the degree of mechanization in the region, and the higher the level of productivity).
	a5: Multiple-cropping index	The higher the ratio (%) of the total area of crops sown or transplanted throughout the year

		to the total area of cultivated land, the higher the cropping index, indicating the greater the number or types of crops planted on cultivated land at the same time, reflects the higher level of land use efficiency and agricultural technology.
Ecological variables	a6: Effective irrigation area	The area of arable land (1000 ha) that can be irrigated normally in general years reflects the drought resistance of arable land and reveals the guaranteed condition of water source of arable land.

3.2.4 Results of Descriptive Statistics

The results of the descriptive statistics are elaborated in Table 2 as follows:

Table 2. Results of descriptive statistics (Self-drawn by the author)

Variable	Obs	Mean	Std.dev.	Min	Max
y	651	33.81726	13.17672	2.924696	64.61509
x	651	1.457389	2.451999	-11.82159	18.93994
a1	651	12.11567	6.624755	0.3	37.9
a2	651	2.796946	0.5542073	1.845	5.646
a3	651	2.74862	3.187517	0.0597902	26.21067
a4	651	2763.184	2687.369	93.97	13353.02
a5	651	130.8073	41.29237	48.76419	242.7062
a6	651	1960.01	1537.002	109.24	6177.59

3.3 Spatial Autocorrelation Model

The spatial autocorrelation model is employed to gauge the level of spatial clustering of a particular attribute and to pinpoint the location of these clusters. In this study, Global Moran's I is utilized to assess the extent of spatial clustering or dispersion of non-grain cropland at the regional scale. In contrast, Local Moran's I is utilized to analyze the spatial distribution of clustering centers and to discern the spatial characteristics of both high and low-value clustering centers of non-grain crops.

$$I = \frac{\left\{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i-\bar{x})(x_j-\bar{x})\right\}}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \tag{4}$$

"w_{ij}" are the elements of the spatial matrix. "X" represents the independent variable. The Moran index I takes values in [-1,1]. $I>0$ means positive correlation, $I<0$ means negative correlation, and $I=0$ means no correlation.

3.4 Model Construction

Prior research has demonstrated significant neighborhood effects associated with non-grain crops, with scholars positing that NGPs activities stimulate nearby cropland operators[35]. Moreover, collective action has been shown to generate spillover effects. The spatial correlation between collective action and non-grain cropland is evident. Hence, this paper employs exploratory spatial data analysis techniques to explore spatial correlations.

Paelinck introduced the spatial econometric model in 1974, which was further refined by subsequent work from Anselin, Elhorst, and other economists[36]. This evolution led to the construction of the spatial lag model (SAR) and the spatial error model (SEM)[37][38]. The SAR model examines the transmission of variables' spillover effects through spatial interactions, while the SEM model investigates the impact of random shocks between variables caused by spatial regional disparities. The expressions for these models are as follows:

$$SAR: lny = \alpha + \beta_1 lnx + \beta_2 lna_1 + \beta_3 lna_2 + \beta_4 lna_3 + \beta_5 lna_4 + \beta_6 lna_5 + \beta_7 lna_6 + \rho \sum_j w_{it} lny + \mu_{it} \quad (5)$$

$$SEM: lny = \alpha + \beta_1 lnx + \beta_2 lna_1 + \beta_3 lna_2 + \beta_4 lna_3 + \beta_5 lna_4 + \beta_6 lna_5 + \beta_7 lna_6 + \lambda \sum_j w_{it} \mu_{it} + \xi_{it} \quad (6)$$

"β" denotes the degree of influence between the independent variables and on the explanatory variables, "ρ" represents the spatial dependence between explanatory variables between neighboring regions, and "λ" is the spatial error correlation coefficient.

3.5 Model Selection

3.5.1 Spatial Correlation Test

Figure 2 displays the results of the spatial correlation test, indicating a positive spatial dependence of non-grain crops. The Moran's I indicator shows a consistent upward trend from 2000 to 2020, with the coefficient of spatial autocorrelation consistently below 1%. These findings underscore the statistical significance of the results, suggesting a significant spatial spillover effect of non-grain crops.

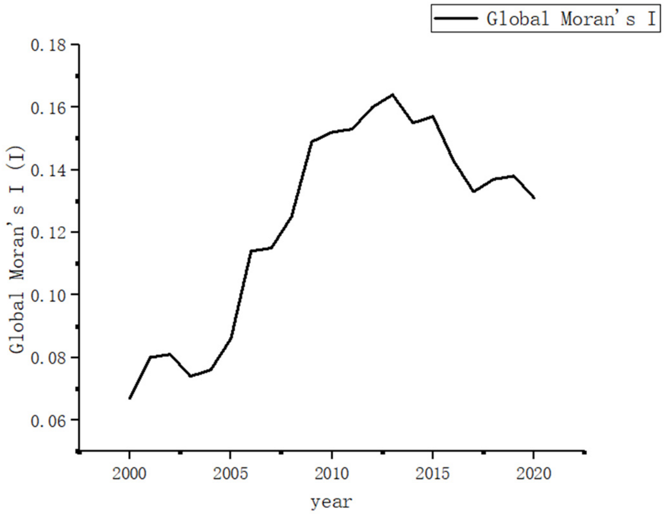

Fig. 2. Spatial autocorrelation diagnostic results (Self-drawn by the author)

3.5.2 Selection of SEM and SAR

This paper employed selection criteria proposed by Lesage and Pace, as well as Elhorst, to choose the estimation models. Initially, the LM test (refer to Table 3) demonstrated that the p-values of the spatial error model were all significant at the 1% level, indicating the appropriateness of the SEM model. Conversely, the p-value of the spatial lag model did not reach significance, leading to its exclusion. The subsequent analysis involved testing the significance of Prob > chi2 values by comparing area-fixed effects, time-fixed effects, and double-fixed effects. Results revealed Prob > chi2 = 0.0000 for the spatial fixed model LR chi2(10) = 282.72, rejecting the null hypothesis and favoring the spatial fixed effects model. Moreover, the Hausman test yielded a statistic of -64.98, aligning with previous research indicating the use of fixed effects. Thus, the spatial fixed effects model of SEM was ultimately selected. Additionally, the paper evaluated the goodness of fit for each matrix and concluded by choosing the geographic distance matrix. This process completed the model selection phase.

Table 3. LM test results (Self-drawn by the author)

Test	Statistic	df	p-value
Spatial error:			
Moran's I	144.24	1	0
Lagrange multiplier	20.022	1	0
Robust Lagrange multiplier	21.787	1	0
Spatial lag:			
Lagrange multiplier	0.087	1	0.768
Robust Lagrange multiplier	1.853	1	0.173

4 Results

4.1 Spatial-Temporal Characterization of Collective Action Dilemmas

Figure 3 and Figure 4 illustrate the collective action dilemma in food production, which have demonstrated an overall increasing trend from 2000 to 2020. Despite reaching a turning point and starting to decline, it remains above its initial level. The answer to the first question posed in the introduction, H1, confirms the presence of a collective action dilemma in achieving sustainable food security.

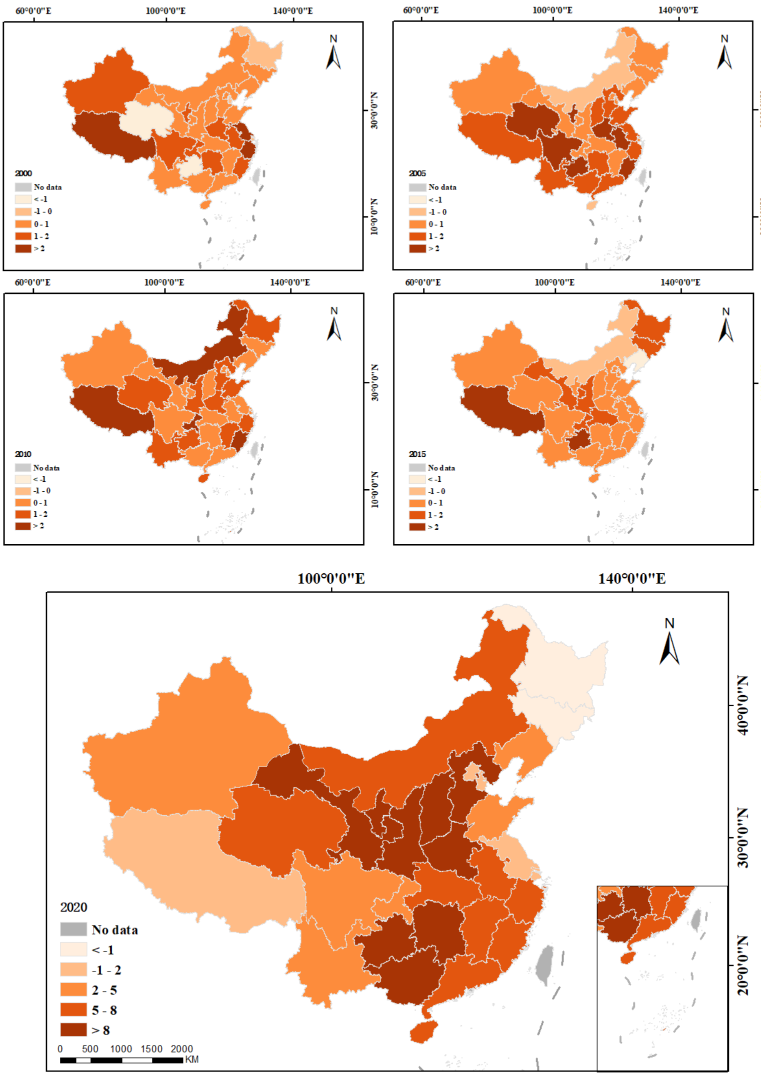

Fig. 3. Spatial and temporal variation in collective action dilemmas (Self-drawn by the author)

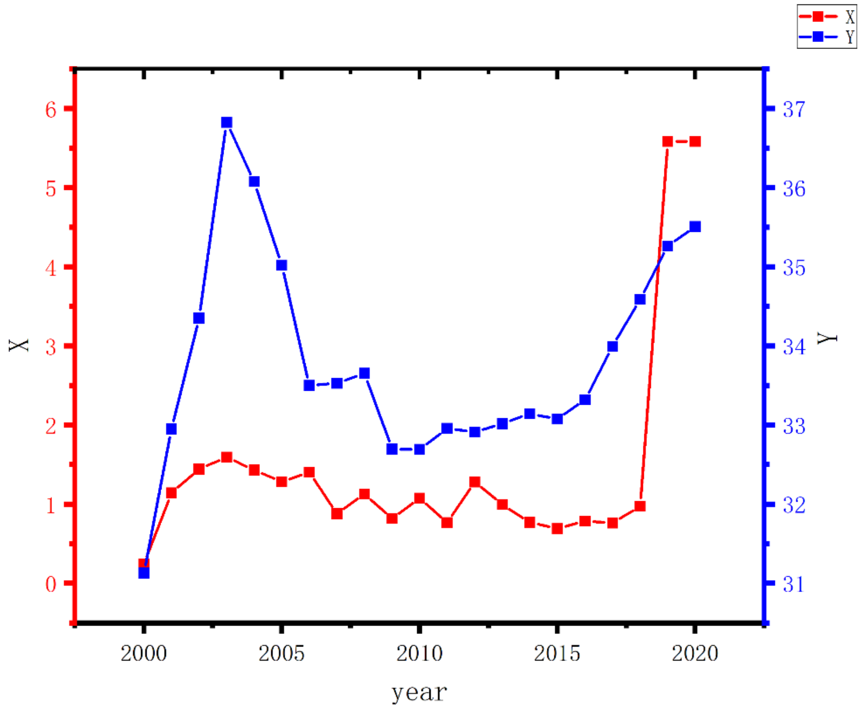

Fig. 4. Line graph of time series changes (Self-drawn by the author)

4.2 Temporal and Spatial Characteristics of NGPs

Cross-sectional comparisons highlight regional disparities in non-grain crop production. Based on supply and demand in the grain market, China categorizes its agricultural production regions into main grain-producing areas, main grain-marketing areas, and balance-of-production and marketing areas. Analysis of non-grain crop measurements reveals a national average level of 34% from 2000 to 2020. However, the inter-provincial gap is substantial, reaching 61%, indicating considerable variability across Chinese provinces. Regional comparisons (Figure 5) indicate an average non-grain crop production level of 27.09% in major grain-producing areas, 44.51% in major grain-selling areas, and 34.96% in regions with balanced grain production and marketing. Notably, main grain-selling regions exhibit the highest non-grain crop levels, while main grain-producing regions show the lowest. A longitudinal comparison suggests a general increase in non-grain crop levels over time. Comparing regional conditions shows that the main grain production areas have superior production, living, and ecological standards compared to the main grain marketing areas and the production-marketing balance areas.(Table 4)

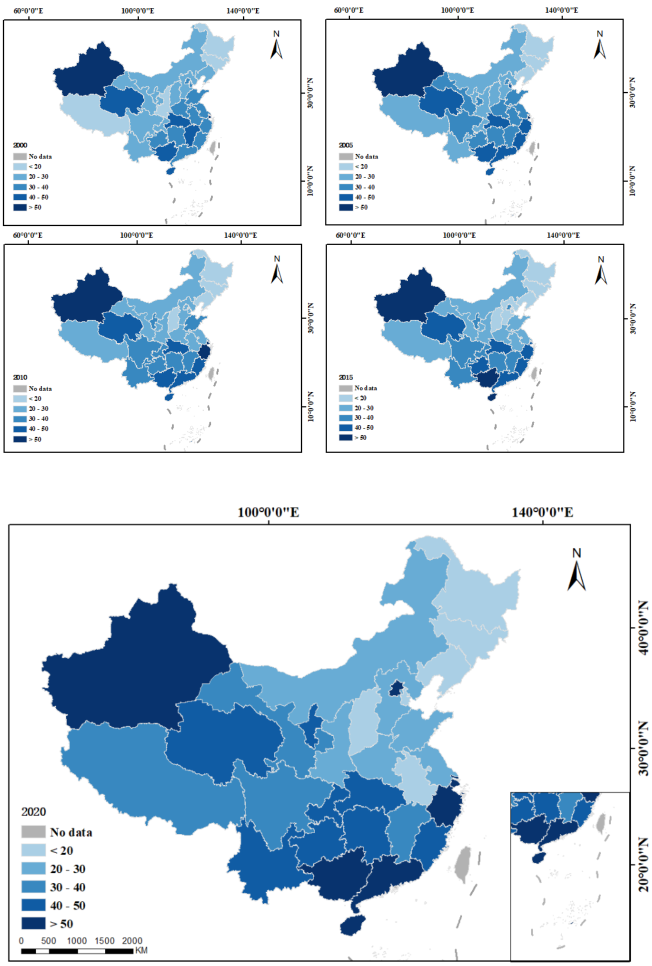

Fig. 5. Spatial and temporal variations in NGPs (Self-drawn by the author)

Table 4. Comparison of conditions in different production regions (Self-drawn by the author)

	Main production area	Major marketing area	Balance area
NGPs	27.09	44.51	34.96
Collective action dilemmas	1.34	1.20	1.76
Life variables	13.03	7.79	13.76
	2.56	2.42	3.31
	1.94	1.23	4.68
Production variables	4757.14	978.21	1542.59
	146.66	139.65	106.45
Ecological variables	3251.62	720.04	1222.63

4.3 Impact of Collective Action Dilemmas on NGPs

4.3.1 Spatial Spillovers from Collective Action Dilemmas

The results of the spatial error model are presented in Table 5. According to the estimation results, it is observed that all coefficients of "Spatial" are significantly positive at the 1% level, indicating a positive spillover effect of the collective action dilemma on NGPs. Moreover, the growth of NGP in each province exhibits strong spatial dependence. The spatial interdependence of Non-Grain Production Income (NGIs) expansion is evident when NGIs expand in neighboring provinces, leading to a relative increase in NGIs within a given region and vice versa. This phenomenon is attributed to structural error shocks, with the collective action dilemma being the underlying cause. Specifically, for every 1 percentage point increase in lnx, the collective action dilemma raises lny by 2.08 percentage points at the 1% significance level. This finding addresses the second hypothesis (H2): Collective action positively impacts NGPs with a spillover effect, consequently exacerbating the negative externality of NGPs and posing challenges to sustainability of food security. The measurement results of the control variables indicate that the coefficients associated with the primary industry output value ratio, urban-rural income gap, arable land replanting index, and effective irrigated area are all significantly negative. These four control variables exhibit a negative spillover effect on non-grain development. Specifically, higher values of the primary industry output, urban-rural income gap, arable land replanting index, and effective irrigated area are correlated with reduced levels of non-grain development in surrounding areas. Instead, they alleviate the prevalence of NGPs in these regions.

Table 5. Impact of collective action dilemmas on NGPs, 2000-2020(Self-drawn by the author)

	(1) ind	(2) time	(3) both
Main			
lnx	0.0208**	0.0325	0.0216**
	(2.7)	(1.7)	(2.75)
lna1	-0.217***	0.0329	-0.251***
	(-5.17)	(1.06)	(-5.86)
lna2	-0.537***	0.675***	-0.628***
	(-4.66)	(5.12)	(-5.25)
lna3	0.0434*	-0.168***	0.0601**
	(2.3)	(-5.17)	(3.07)
lna4	0.142***	-0.196***	0.178***
	(3.66)	(-4.43)	(4.43)
lna5	-0.0451	0.580***	-0.0344
	(-0.97)	(8.72)	(-0.73)
lna6	-0.501***	0.0249	-0.492***
	(-7.68)	(0.57)	(-7.41)
Spatial			
lambda	0.847***	0.643***	0.712***
	(31.64)	(8.44)	(11.67)

Variance			
sigma2_e	0.0218***	0.155***	0.0222***
	(17.73)	(17.7)	(17.66)
r2	0.0365	0.253	0.029
N	651	651	651

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

4.4 Heterogeneity Analysis

As highlighted earlier, spatial heterogeneity characterizes NGIs and collective action dynamics. Additionally, variations across geographical regions influence the impact of collective action dilemmas on non-grain sectors. Existing studies have primarily examined single regions empirically, with few delving into the nuanced cross-sectional distinctions among the three regions relevant to food production. This researcher posits that sub-regional analysis not only enhances the article's logical structure and argumentative depth but also, most significantly, facilitates the formulation of precise policy recommendations for zoning control.

The findings depicted in Table 6 underscore the divergent behaviors across different regions. The significant positive spillover effect observed in primary grain-producing regions is particularly noteworthy, aligning with the overarching results. This phenomenon likely emanates from the pivotal status of these regions as epicenters of grain production in China, thereby wielding direct and decisive influence over overall degrowth dynamics. Conversely, major grain marketing areas exhibit pronounced negative spillover effects. This contrast can be attributed to policy imbalances favoring non-major grain marketing areas. Consequently, the comparative advantages of cultivating food in major grain marketing areas are attenuated relative to neighboring regions.

Based on the analysis of control variables, the main grain-producing region stands out among the three regions in terms of the share of primary output value, governmental agricultural expenditure, and effective irrigated area. These factors, however, exhibit significant negative effects on NGPs. Conversely, in the main grain marketing region, the ratio of primary output value to the total power of agricultural machinery significantly promotes NGPs, further encouraging this sector. Although governmental agriculture-related expenditures, cropland replanting index, and effective irrigated area in the main grain marketing region negatively impact non-food production, these metrics are the lowest among the three regions. In the production and marketing balance area, where these elements are at an intermediate level, the development of non-food production is correspondingly moderate.

Table 6. Heterogeneity results (Self-drawn by the author)

	Main production area	Major marketing area	Balance area
Main			

lnx	0.0518*	-0.0277*	-0.00136
	(2.18)	(-2.37)	(-0.13)
lna1	-0.403***	0.487***	-0.111***
	(-4.43)	-6.03	(-3.82)
lna2	1.555***	0.427	-0.667***
	(-5.94)	(-1.14)	(-5.14)
lna3	-0.175**	-0.115***	0.0436
	(-2.64)	(-4.15)	(1.30)
lna4	0.165*	0.434***	0.285***
	(2.3)	(4.76)	(5.31)
lna5	0.974***	-0.449***	0.13
	(10.91)	(-6.23)	(1.65)
lna6	-0.491***	-0.255**	-0.341***
	(-5.47)	(-2.64)	(-3.87)
Spatial			
lambda	0.35	-0.861***	-1.049***
	(1.89)	(-10.07)	(-5.21)
Variance			
sigma2_e	0.0856***	0.00658***	0.00925***
	(11.33)	(7.45)	(9.96)
r2	0.676	0.0111	0.016
N	273	147	231

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

4.5 Robustness Analysis

In order to enhance the robustness of this study's measurements, an expansion is undertaken to explore the economic linkages among regions. In this paper, the conventional matrix is substituted with an economic distance weight matrix test. Notably, the test outcomes affirm that the effect of the collective action dilemma on non-grain sectors remains notably positive, persisting below the 1% significance level. This serves to reassert the credibility of the study's findings. Furthermore, Wald and LR tests have been executed, with the results aligning in favor of the Spatial Error Model (SEM) as the preferred analytical framework.

5 Discussion and Conclusions

5.1 Implicit Policy Recommendations on the Impact of Collective Action Dilemmas on NGPs

In the context of challenges such as the low comparative efficiency in grain cultivation and rapid urbanization, grain producers have acted as rational agents by migrating away from rural areas[23]. Despite China's vast rural population, which might suggest an abundant workforce for food production, grain producers believe that their departure does not threaten the continuity of grain supply, thanks to sufficient reserves. However, collective action dilemmas have emerged, particularly among producers in critical grain marketing regions and those involved in balanced grain production and distribution. Consequently, the sustainability of food supply is at risk, along with societal food security. Therefore, it is crucial to examine the impact of resolving collective action dilemmas on non-grain agricultural sectors, which forms the central inquiry of this paper.

On the one hand, the efficacy of collective action's positive externalities has its limits, debunking the notion that larger scale always equates to better outcomes. This study underscores the necessity of identifying the equilibrium point between farmers' participation in food production, considering marginal costs and marginal incomes, to attain an optimal level of utility in collective action. This pursuit ultimately offers novel approaches toward achieving sustainable food security. Selective incentives emerge as a potential equilibrium point. Within the framework of traditional collective action theory, Olson's concept of "selective incentives" presents a fresh perspective for mitigating issues inherent in collective action dilemmas, such as the "tragedy of the commons," "opportunism," and "free riding". This approach not only incentivizes farmer engagement in food production but also addresses the hitchhiking dilemma, as Zhao Dingxin aptly notes, emphasizing the importance of rights in resolving such dilemmas. Therefore, the selective incentives proposed for producers extend beyond mere financial compensation, encompassing status-rights rewards as well. This marks the primary solution outlined in this paper.

Within the domain of food production and sustainable food security, collective action transcends mere participation by producer groups[39]. The institutional framework for collective action encompasses a spectrum of stakeholders, including consumers, central and local governments, and primary production and marketing entities. A monocentric governance model not only incurs higher governance costs but also falls short of achieving governance objectives due to inherent flaws. Therefore, a holistic solution should entail the involvement of relevant stakeholders to establish a governance pattern integrating multiple actors from the government, the market, and the public. This approach resonates with the principles of the new collective action theory. Since the 1980s, scholars like Eleanor Ostrom and Vincent Ostrom have refined and expanded collective action theory by revising Olson's product classification criteria and rational choice model. They have enriched governance mechanisms by emphasizing new institutional supply, credible commitment, and mutual supervision. Their proposition aims to foster the organic synergy of "active government," "effective market," and "spontaneous order" by aligning the interests and behaviors of all social entities. This endeavor aims to achieve the objectives of "effective government," "efficient market," and "spontaneous order," offering an alternative avenue for realizing sustainable food security.

As a collective, we aim to bolster the safeguarding of small and marginal farmers as integral contributors to the agricultural landscape [14]. Scholars have contended that ensuring food security should not come at the expense of the welfare of food producers, and national prosperity should not be achieved through their exploitation [17]. We aspire to chart a course toward sustainable food security that simultaneously honors and supports the livelihoods of farmers. This dedication to farmers serves as the foundational principle and overarching objective of this research paper. This marks the conclusion of the inquiry posed in the introduction.

5.2 Conclusions

Commencing from the inherent tension between food security and food sovereignty, this paper advocates for the pursuit of a sustainable pathway to food security. Employing collective action theory as a guiding framework, the study delves into the dynamics of NGPs and examines the interplay between free-riding behavior and NGPs using official statistical data gathered from 31 provinces across China. Subsequently, the research arrives at the following conclusions:

(1) The collective action dilemma in achieving sustainable food security is notably more severe in the main food-producing areas than in the main food-marketing areas and the balanced food production and marketing areas. Notably, collective action dilemmas are more pronounced in primary food marketing areas and regions with balanced food production and marketing than in primary food production areas.

(2) Using data analysis, this paper examines the spatial and temporal evolution of nongrain development in China from 2000 to 2020. Spatially, significant regional disparities in nongrain distribution are observed across China. While primary grain-producing areas exhibit the lowest levels of NGPs, primary grain-marketing areas present the highest levels, with regions demonstrating balanced production and marketing showing intermediate levels of NGPs. However, this pattern is transforming. Temporally, the level of nongrain demonstrates an overall upward trajectory, depicting a roughly "N"-shaped trend of change.

(3) Employing a spatial error model for empirical analysis, this study reveals a positive spillover effect of the collective action dilemma on NGPs. In the main grain-producing areas, the proportion of output value from the primary industry, government agricultural expenditure, and effective irrigated area significantly impede non-food production on arable land. Conversely, in the main grain marketing areas, the proportion

of primary industry output value and the total power of agricultural machinery significantly enhance non-food production on arable land. The balanced production and marketing areas exhibit moderate levels of production, living standards, and ecological conditions, leading to a corresponding intermediate level of non-food production among the three regions.

In light of these findings, the paper delves into potential solutions for addressing the collective action dilemma within the context of sustainable food security, providing a blueprint for emulation by other developing nations.

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