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The Spatial Analysis of the Effect of Off-Farm Income on the Food Security of Rural Households in Iran: Application of a Spatial Econometric Approach with Panel Data

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Abstract

Background: Providing food security to rural households is one of the goals pursued in national development plans. Therefore, off-farm income provides more financial resources to rural households and thus increases their food security. Given the role of food security in human health and development, the present research aims to explore the spatial effects of off-farm income on the food security of rural households in all provinces of Iran.

Methods: The status of food security of rural households in Iran was determined using data from 206963 Household Income and Expenditure Surveys and the recommended dietary for the Iranian population. Besides, the effectiveness of off-farm income on food security of rural families along with other effective factors was investigated the first time using the panel spatial autoregressive (SAR) model for the period from 2006 to 2016 with Stata software.

Results: The results from the SAR model suggested that off-farm income has a positive and significant effect on the rural food security index. On the other hand, the significant value of the spatial lag coefficient of the dependent variable confirmed the existence of spatial effects, indicating that off-farm income has a positive and significant effect on food security.

Conclusion: Given that agricultural activities are mainly seasonal, off-farm activities along with conventional agricultural activities can improve the food security of rural households and prevent their migration to cities.

Keywords: Food security, Off-farm income, Spatial panel

Introduction

Achieving consistent food security as the main goal of development policies and access to adequate food and nutritional health have always been highlighted as the main components of development and important infrastructures for nurturing future generations (1). Food security refers to the physical and economic access of all members of society, throughout life, to adequate and healthy food to have a healthy

and active lifestyle. Furthermore, household income is an important factor in ensuring food security in a social system. Another important factor in ensuring food security in the community is the taste and nutritional knowledge of families in how to allocate funds for the best available food and how food is distributed in the family. Food security is ensured when the per capita food basket of the family is properly selected and prepared, and food is cooked in sufficient amounts and properly for family members so that their cells and organs of the body have access to healthy and essential nutritional elements and foods (2).

People, as the main members of society, have needs, the most important of which are healthy nutrition and food security. According to FAO, food security is ensured when a family has access to safe food in adequate and diverse amounts to meet the needs of its members (2). Food insecurity threatens the vital values and, consequently, the national security of a country. Food insecurity is the cause and facilitator of poverty, famine, and hunger, and is a serious threat to a nation. Undoubtedly, having enough food is a human right, and depriving people of it for any reason is a crime. Food insecurity drastically reduces the storage of individuals' social capital as well as the significance of human and religious norms and values as highlighted in our religious and national teachings (3).

Food insecurity surveys in 2017 show that despite the considerable economic growth of many developing countries, about 821 million people in the world suffer from hunger and food insecurity. Meanwhile, at least 70% of the world's poor population lives in rural areas (4). Moreover, a review of the evolution of agricultural production with the growth of the world population over the past 50 years shows that due to the increased cultivation area and the Green Revolution, agricultural production has increased in proportion to the population, but people in different countries have less access to produced food and this has led to latent hunger and food insecurity on a large scale (5, 6). Various studies conducted in Iran have shown that rural households have a lower level of food security compared to urban households and are more vulnerable to food insecurity (7). Accordingly, the non-agricultural economy in rural areas has been recognized as an emerging strategy to create employment and increase the income of rural households (8) and its positive effects on poverty reduction have been studied (9, 10, 11, 12, 13). However, the effects of non-agricultural activities on the food security of rural households have rarely been addressed in the literature (14).

Some of the most important factors affecting the food security of a rural household can be the number of household members, income from agricultural activities, income from non-agricultural activities (off-farm income), age of the head of the household, level of education, Gini coefficient, food price index (food inflation), the gender of the head of the household, number of people working in the household, the area of agricultural land owned by the household, and other influential internal and external factors.

Abebaw et al. (15) examined the impact of a food security program on household food consumption in Northwestern Ethiopia using the logit approach and showed that the food security program has a significant effect on food calorie intake. Besides, the effectiveness of an integrated food security program largely depends on factors such as household size, land ownership, and the gender of the head of the household. Tithy et al. (16) analyzed the effects of income diversification on the food security of rural households in Rajshahi District, Bangladesh. Their results showed that three factors including the age of the head of the household, educational status of the head of the household, and the number of household members were significantly related to the food security index of rural Bangladesh households. Income diversification also had a positive but insignificant effect on household food security in Rajshahi District. Therefore, implementing well-defined programs to increase household income can increase food security. Babatunde and Qaim (17) examined the effect of off-farm income on food security in Nigeria and concluded that such incomes have a positive effect on both food security and the quality and quantity of food. Cheraghi et al. (18) investigated the role of non-farm incomes in the food security of Iranian rural households in Zanjan. The results showed that 73% of rural households earn less than 40% of their income through the non-agricultural sector and there was a significant relationship between increasing non-agricultural incomes and improving food security. Zera' at Kish and Kamaei (19) examined the factors affecting food security in rural

farming households in Kohgiluyeh and Boyer-Ahmad province. The results showed that 46% of rural households had food security. They also found the income of the head of the household, the ratio of food expenses to the total household expenses, and the size of the farm had a positive effect on the food security of the household. On the other hand, the gender of the head of the household, the education level of the head of the household, and the household size had a negative relationship with household food security.

According to the studies reviewed above, the income of the head of the household has a positive effect on household food security. These studies also suggest that income from off-farm activities has a positive and significant relationship with improving household food security. Although the agricultural sector is the main source of income for the majority of rural communities in developing countries, surveys have shown that most rural households rely on non-agricultural economic activities to meet their needs. Therefore, by creating income diversification, they take action to make a living and increase the food security of their families. Moreover, a review of the country's household expenditure and income statistics shows that people with low annual incomes are more likely to live in rural areas (20). Therefore, examining income distribution and income diversification techniques and their relationship to the food security of rural households can be effective in policies made by the public sector. Considering the role of food security in health and human development, this study seeks to investigate the spatial effects of off-farm income on the food security of rural households in all provinces of Iran. An awareness of the food security status of the rural community and the factors affecting it will be a valuable help to health policymakers, designers of rural development programs, and other related organizations to take positive steps to improve human development and ultimately rural development. This study also explores the direct and indirect effects of income from agricultural activities and off-farm income on food security of rural households in each province and neighboring provinces and the impact of other factors on food security in each province and neighboring provinces.

Methods

The data in the table of the recommended dietary intake of energy, protein, and macronutrients prepared by the Office of Community Nutrition Improvement, Ministry of Health and Medical Education were used to determine the food security of rural households. According to this table, the per capita consumption of various foods during a day is an average of 1563 grams per person, which is equivalent to 2573 kcal per day. The Income and Expenditure Survey was used to determine food security. To this end, the dietary intake was calculated using the data in the table and the expenditure and income information, and the resulting value was divided by 30 days to obtain the dietary intake per day. Given that the unit for measuring the household expenditure and income is in kilograms, the dietary intake value was multiplied by 1000. The household dietary intake (g) was calculated from the following items and for each province separately as shown in Table 1.

Table 1. The recommended dietary intake of energy, protein, and macronutrients

Row	Foodstuff	Daily intake (g per day)	Energy (Kcal)
1	Rice	95	339
2	Bread	310	879
3	Spaghetti	20	72
4	Red meat	38	106
5	White meat	64	82
6	Dairy products	250	207
7	Egg	35	45
8	Oil	35	315
9	Fruits	280	141
10	Vegetable	300	85
11	Potato	70	57
12	Sugar	40	155
13	Grains	26	91
14	Total	1563	2574

The research population included all ordinary households and extended families (households residing in a single place) in rural areas of Iran. Ordinary non-resident and institutional households were excluded from the study. The required data were collected through face-to-face interviews with the selected households and the questionnaires completed by them. Furthermore, the secondary data including the household expenditure and income data were extracted from the general population and housing census file (20). The participants in the research sample were selected in three steps using probability sampling. To assess food security, the Household Income and Expenditure Survey from 2006 to 2016 was used. To this end, the data from 206963 household surveys for a period of 11 years were extracted, covering an average of 18815 households per year. Besides, the survey data were prepared for each province separately; food security indexes were measured for 30 provinces for each year and the related values were used in the data analysis. Given that Alborz Province was separated from Tehran Province since 2012 and the independent data for this province were not accessible for the period before 2012, Alborz Province was not considered as an independent province, and one dataset was used for the two provinces.

Since the corpus used in this study included cross-sectional data and time-series data, panel data method was used to assess factors affecting food security. Besides, to consider the effect of the proximity of the provinces on food security factors, spatial econometrics was used in this study. The distinguishing feature of spatial econometrics from conventional econometrics is the use of spatially interdependent data. Two problems with data that include a spatial component are spatial correlation between observations and spatial heterogeneity that are mostly ignored by conventional econometrics (21, 22). The models used in spatial econometrics are the first-order autoregressive (FAR) model, the panel spatial autoregressive (SAR) model, the spatial error model (SEM), the spatial Durbin model (SDM), and the spatial autocorrelation (SAC) model. The main difference between these models is the location of the spatial weight matrix to eliminate spatial correlation (23, 24).

To address the spatial effects of off-farm income on food security of rural households by taking into account the proximity of the provinces (the common border), the spatial econometric method with panel data was used. The research model was estimated using the panel spatial autoregressive (SAR) model with the maximum likelihood estimation (MLE) method. In this model, the dependent variable y is affected by the values of the dependent variable in adjacent units. The model is expressed as follows:

$$Y_{it} = \rho \sum_{j=1}^{n} W_{it} Y_{it} + \sum_{k=1}^{k} \beta_k x_{ki} + \varepsilon_{it} = \rho WY + X\beta + \varepsilon_{it} \quad \varepsilon_{it} \sim N(0, \sigma^2 I_n) \qquad (1)$$

Where Y is the $n \times 1$ vector of the dependent variables and x represents the $n \times k$ matrix that contains the explanatory spatial interrupt coefficient, the standardized weight matrix, and the error term, respectively. The research model is expressed as follows:

$$Yrural_{it} = f(Fi_{it}, OFI_{it}, PFI_{it}, GINI_{rit}) \qquad i = 1, 2, \dots, 30 \qquad t = 1, \dots, 11 \qquad (2)$$

$$logYrural_{it} = \alpha + \rho W logYrural_{it} + \beta_1 logFi_{it} + \beta_2 logOFi_{it} + \beta_3 logPFi_{it} + \beta_4 logGINI_{rit} + \varepsilon_{it} \quad \varepsilon_{it} \sim N(0, \sigma^2 I_n) \qquad (3)$$

Where *Yrural* is the food security index of rural households, *Fi* is the agricultural income of rural households, *Ofi* is the off-farm income of rural households, *Pfi* is the food price index, and GINI is the Gini coefficient taken as the income distribution index in rural areas in different provinces of Iran. Besides, i = 1, 2, …, 30 indicates the number of provinces, and t = 1, 2, …, 11 is the years under study. The statistical analysis was performed on the latest data available at the Statistics Center of Iran for the period 2006-2016.

Before estimating the spatial econometric model, it is necessary to examine the spatial correlation. For this purpose, the Moran test with the null hypothesis of non-spatial correlation

was used. Moran statistic is the most common test for detecting spatial correlation in error terms of regression models. Lagrange multiplier error and Lagrange multiplier lag tests were used to detect spatial correlation in error terms and spatial correlation in observational data of the dependent variables, respectively. If the null hypothesis of non-spatial correlation in the error terms is rejected, the spatial error model (SEM) is used, and if the null hypothesis of spatial non-dependence in the observational data of the dependent variables is rejected, the panel spatial autoregressive (SAR) model is used. However, if both null hypotheses are rejected, the LMLag_Robust test is used for the SAR model and the LMError_Robust test is used for the SEM model. Additionally, the Hausman test is used to select one of the fixed or random-effects models. The null hypothesis of the Hausman test is a random-effects model as opposed to the hypothesis of a fixed-effects model (25, 26). Stata14 software was used to run the spatial econometric model.

Results

The spatial matrix used in this study is a spatial proximity matrix, which is a symmetric matrix based on the data analysis method. Therefore, the reliability test of non-spatial variables of the model alone is sufficient and there is no need to examine the reliability of the spatial matrix. The Levin-Lin-Chu method as a unit-root test is used to examine the stationary or non-stationary variables in the model. Levin, Lin, and Chou argue using a unit root test to analyze mixed (panel) data is more powerful than using a unit root test for each cross-sectional dataset separately. The null hypothesis in this test indicates that the time series has a unit root and the alternative hypothesis shows the stationary time series. The results of the reliability test in Table 2 indicate that variables were stationary and therefore there is no problem in estimating the spatial analysis of the rural household income.

Table 2. The results of the stationary test of the variables

Variable	Definition	Statistic	P-value	Result
Yrural	The logarithm of food security	-10.89	0.0000	Stationary
Fi	The logarithm of farm income	-8.46	0.0025	Stationary
Ofi	The logarithm of off-farm income	-41.0117	0.0000	Stationary
Pfi	The logarithm of the food price index	-12.0163	0.0000	Stationary
Ginir	The logarithm of the income distribution	-8.8137	0.0006	Stationary

In spatial econometric models, it is better to first consider a general model and then test spatial correlation and spatial autocorrelation between error terms to find out which model accounts for the data more effectively. In addition, the effectiveness of the panel data model and the pool data model was assessed using the Ciao test (or cross-section F-test). Accordingly, the null hypothesis indicating the use of the pool data model was rejected and the alternative hypothesis supporting the use of the panel data model was confirmed. Before estimating the model, it is necessary to test the existence of spatial correlation and autocorrelation between the error terms. Moran's I test was used to assess spatial correlation in error terms. The null hypothesis of this test indicated the existence of no spatial correlation. If the Moran's I statistic is greater than 1.96, the null hypothesis that there is no spatial correlation in the error terms is rejected. Given that the Moran's I statistic was equal to 9.568 which is greater than the critical value of 1.96, the Moran's I statistic confirms the existence of spatial autocorrelation and the results of the standard regression estimated with OLS are no longer reliable. Therefore, the problem of spatial autocorrelation must be solved. For this purpose, the spatial autoregressive (SAR) model and the spatial error model (SEM) can be used. The results of LM Error and LM Lag tests displayed in Table 3 showed that LMLag and LMError statistics were statistically significant confirming the existence of spatial correlation and significant differences between those models as was estimated by the OLS method. Given the significance of the LMLag -Robust statistic and the non-significance of the LMError-Robust statistic, the spatial correlation was of spatial lag type and the spatial autoregressive (SAR) model should be used for model estimation.

Table 3. Lagrange multiplier lag tests

Statistic	LMlag_robust	LMerror_robust	LMlag	LMerror
Value	3.984	2.226	89.897	88.139
P-value	0.046	0.136	<0.001	<0.001

After examining the spatial effects tests, the Hausmann test was used to select the fixed-effects or random-effects models. This test was performed at different confidence levels and the value of the spatial Hausmann statistic was obtained. It is then compared with critical values. If the obtained values are greater than the critical values, the null hypothesis is rejected, and the fixed-effects model is used for data analysis. The X^2 value is 5.35 (P-value = 0.499), confirming the rejection of the fixed-effects model versus the random-effects model. Accordingly, the factors affecting the food security of rural households in Iran were assessed using the panel spatial autoregressive (SAR) model with random effects as shown in Table (4).

Table 4. The results of estimating the random-effects SAR model

Variable	Definition	Statistic	Confidence interval (CI)	P-value
ginir	The logarithm of the rural income distribution	-0.068187	-0.132 < ginir < -0.0041	0.037
pfi	Logarithm of food price index	-0.0882523	-0.139 < pfi < -0.0366	<0.001
fi	Logarithm of farm income	0.3350876	0.260 < fi < 0.409	<0.001
ofi	Logarithm of off-farm income	0.1000759	0.0484 < ofi < 0.151	<0.001
α	Intercept	0.0861496	-0.357< α < 0.529	0.703
ρ	Spatial lag coefficient	0.681321	0.612 < ρ < 0.749	<0.001
R^2		0.8825	-	-
Log-Likelihood		183.6564	-	-

The results of estimating the random-effects SAR model showed that the coefficient of determination (R^2) was 0.88, indicating that about 88% of variations in the food security index in rural households are due to changes in explanatory variables and spatial correlation (spatial lag).

Besides, the spatial regression coefficient (ρ) was positive and statistically significant. Therefore, the spatial estimation of the model is justifiable. In fact, the significance of the regression coefficient indicates the existence of a spatial correlation between observations and shows the extent to which the changes in the dependent variable depend on its changes in adjacent areas. The interpretation of this coefficient is possible by decomposing the total effects into direct effects and indirect (spillover) effects.

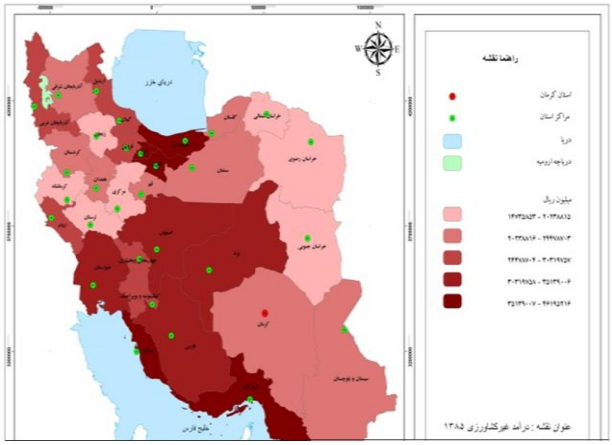
Table 5. The analysis of direct, indirect, and total effects

Variable	Direct effects			Indirect effects			Total effects		
	Statistic	CI	P-value	Statistic	CI	P-value	Statistic	CI	P-value
gini	-0.13846	-0.276< gini <-0.0007	0.049	-0.07822	-0.152 < gini< -0.0038	0.039	-0.21668	-0.42< gini <-0.006	0.043
pfi	-0.1888	-0.301 < pfi < -0.075	0.001	-0.10625	-0.162 < pfi< -0.0501	0.000	-0.29509	-0.460< pfi < -0.129	<0.001
fi	0.67668	0.568< fi <0.785	<0.001	0.38427	0.318< fi <00450	0.000	1.0609	0.939< fi <1.18	<0.001
ofi	0.21420	0.098< ofi <0.329	<0.001	0.12050	0.064< ofi <0.176	0.000	0.33470	0.167< ofi <0.501	<0.001

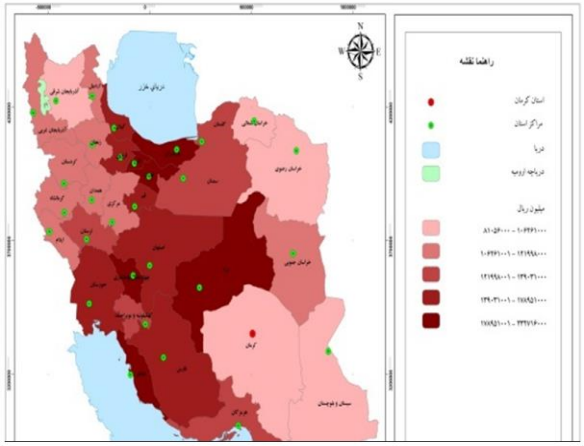
As can be seen, the direct and indirect effects of farming and off-farm income on food security in each province and neighboring (border) provinces are positive and significant. Although off-farm income values are significant, they are very small compared to farm income values, indicating a lower elasticity of food security than off-farm incomes among villagers. If the logarithm of off-farm income (OFI) in province *i* increases by 1%, the logarithm of food security index in the same province increases directly by 0.21%. On the other hand, if the average off-farm income (OFi) in rural households in the adjacent provinces

changes by 1%, the logarithm of the household food security index increases indirectly by 0.12%. Besides, if the off-farm income logarithm (OFi) increases by 1% in all provinces, the index food security in province *i* will increase by 0.33%. It was also found that direct and indirect effects of the Gini coefficient, the food price index, and the average farm income on food security of rural households in each province and neighboring provinces were significant, with the difference that income has a positive effect and the other variables have a negative effect. These results highlight the presence of intra-provincial and inter-provincial spillovers. In addition, the sum of the direct and indirect effects of the variables is equal to the total effect of each of them.

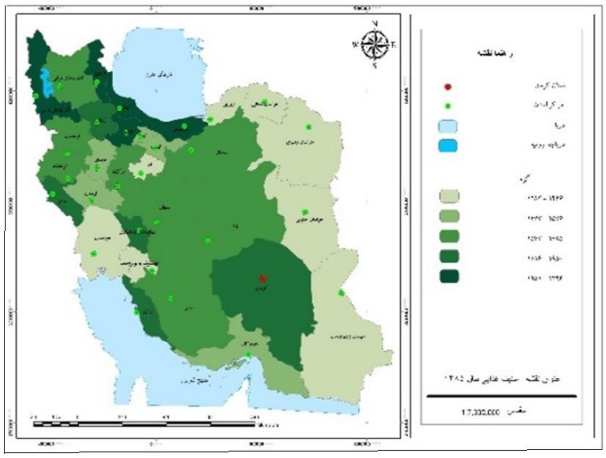
The results were demonstrated in a graphic form using the GIS software. Figure 1(a) to (d) shows the geographical distribution of food security and off-farm income indexes in 2006 and 2016 in Iran:



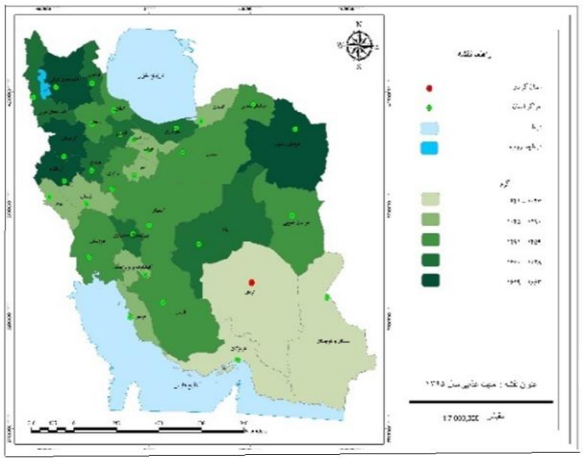
(a) Off-farm income in 2006



(b) Off-farm income in 2016



(c) Food security in 2006



(d) Food security in 2016

As can be seen in the figures above, off-farm income in the southeastern provinces declined over the past 10 years, negatively affecting the food security of these provinces. Moreover, with the decrease of off-farm activity in the Persian Gulf provinces in southern Iran during the last 11 years, the food security of these provinces also decreased as shown in Figure 1(a) to (d). It should be noted that the increase in off-farm income of rural households in the eastern provinces has increased the food security of rural households in these provinces. This improvement in food security is more evident in Yazd Province due to the increase in off-farm income. Declining food security due to declining off-farm activity in the northwestern provinces is also evident over the past 11 years. The central provinces of Iran do not show much change due to the lack of change in off-farm income. Therefore, as shown in the figures above, there is a positive and significant relationship between food security and income from off-farm

activities, which are very small compared to farm incomes, indicating less elasticity of food security compared to off-farm income among villagers.

Discussion

The present study showed that of the factors affecting food security, the Gini coefficient had a negative and significant effect on the food security index of rural households in Iran. Equal income distribution in the society, especially in rural areas, plays an important role in enhancing the purchasing power and ability of individuals to supply food. In contrast, high inequality in income distribution causes those rural areas to move towards unsustainable food security. Applanaidua et al. (27) addressed the effect of macroeconomic indicators on food security in Malaysia and showed there is a significant relationship between the Gini coefficient and food security status, with the Gini coefficient affecting food security across the country. Accordingly, Salem and Mojaverian (28) reported the negative and significant effect of the Gini coefficient on the food security status of urban households in Iran. Amirzadeh Moradabadi et al. (29) also highlighted the effect of income distribution inequality in reducing food security of rural households in Iran.

The results of the present study showed that the logarithm of farm income (fi) has a positive and significant effect on the food security index of rural households and the logarithm of off-farm income (ofi) has a positive and significant effect on the food security index of rural households. The results of studies by Applanaidu et al. (27) in Malaysia, Dithmer and Abdulai (30) in 151 countries, and Faridi and Wadood (31) in Bangladesh confirmed the positive effects of income on household food security.

The present study also showed that the logarithm of the food price index (pfi) has a negative and significant effect on the food security index of rural households. Accordingly, as the food price index rises, rural households are at a higher risk of not receiving nutrients and the likelihood of receiving the minimum amount of energy needed to perform daily activities, and consequently, the probability of food security decreases. Fluctuations in food prices, especially for basic goods, have a great impact on consumer behavior. Furthermore, increasing food prices, especially when incomes are not balanced and commensurate with rising food prices will reduce the access of people especially vulnerable groups to food. This, in turn, adversely affects the food security of the community and the government must take measures to provide the energy needed by individuals, households, and the community by putting into place effective support policies. Other studies by Applanaidua et al. (27) in Malaysia, Dithmer and Abdulai (30) in 151 countries, Ozturk (32) in selected South African countries, and Zhou et al. (33) in Pakistan confirmed the negative effect of price index on food security. Moreover, Gustafson (34) also showed that rising food prices negatively affects the food security of Indian households.

Overall, the data in this study showed that off-farm income has a positive and significant effect on the food security index of rural households. However, off-farm income values are very small compared to farm income values, indicating a lower elasticity of food security than off-farm incomes among villagers. On the other hand, the significant value of the spatial coefficient of the dependent variable confirms the existence of spatial effects. Therefore, the direct and indirect effects of the off-farm income index on food security in each province and neighboring provinces are positive and significant, indicating the existence of intra-provincial and inter-provincial spillovers. In general, increasing the farm income of rural households can play an effective role in increasing their food security. Given that a large part of the income of rural households comes from agriculture, governments should implement effective plans to support the purchase of agricultural products (guaranteed purchase), and distribution of agricultural inputs at determined prices. Furthermore, by developing suitable cultivation patterns, creating value chains of agricultural products, eliminating intermediaries in trading agricultural products, increasing productivity in agricultural products, and creating infrastructure to deliver agricultural products to consumer markets as soon as possible, governments can increase farm income of rural households. In addition, considering the effective role of non-farm income in increasing the food security of rural households, governments should provide the necessary support to rural businesses by granting low-interest loans, creating rural micro-funds, and increasing the financial capacity of rural communities.

Conclusion

The present study showed Iranian rural

households have generally a moderate level of food security and food security in the southern and northwestern provinces has undergone a declining trend in the past eleven years due to a decrease in farm and off-farm income levels. However, food security has increased in the eastern provinces due to higher income from agricultural and non-agricultural activities. Furthermore, the income level of Iranian rural households is more affected by the production of crops in their province due to self-reliance activities. Income from agricultural and non-agricultural activities is the main factor for households affecting their purchase and consumption of food products. In fact, household income is the most important factor in most cases. Accordingly, the present study showed a positive and significant relationship between food security and income from off-farm activities.

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Conflict of interest

The authors declared no conflict of interest.

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