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CHALLENGES OF FOOD SECURITY IN THE GULF COOPERATION COUNCIL COUNTRIES: AN EMPIRICAL ANALYSIS OF FIXED AND RANDOM EFFECTS

Purpose. *This research aims to identify the challenges of the food security indicators in the Gulf Cooperation Council (GCC) countries for the period 2000–2020.*

Methodology / approach. *The dataset of this study includes the annual secondary data covering the time 2000–2019 of the six GCC countries. The dependents variables represent the food security indicators whereas, the independents variables (explanatory) represent the challenging factors of the food security at the macro-level data. All the studied variables are reshaped in the balanced panel form; thus, the study uses a long panel, it has many periods (T = 20 years) but few entities (n = 6 countries of GCC) with the total 120 observation. The study applies three alternatives to panel data analysis.*

Results. *The results show that population is a significant driver of food security challenges in the GCC countries. Moreover, food price inflation has a significant impact on the food availability and stability but show no significance on food access and utilization. Fertilizer consumption causes significant problems with food use. The results show that there is an evidence of significant differences in food security across the GCC countries. The random-effects estimators of regression coefficients of food availability and stability challenges are more statistically efficient than those for pooled ordinary least square and fixed effects. While the fixed effects estimators are most preferred for the coefficients of food access and utilization challenges.*

Originality / scientific novelty. *Most scientific articles are mostly focused on examining the food security challenges from one separate aspect: economics, climate, or social aspects. Thus, the scientific novelty of the study is to investigate the combination of the food security challenges, social, economic, and agri-environmental factors in the GCC oil countries.*

Practical value / implications. *Through this research, it is proposed that decision-makers embark on interferences that stimulate food security to meet the continual increase in population also future research should be applied to the other factors that challenged food security.*

Key words: *food security indicators, population, food price inflation, gross domestic product, fertilizer consumption, panel data analysis, GCC countries.*

Introduction and review of the literature. Food security has been considered a significant global crisis for the past several years, according to FAO's report [1], and based on the Food Security and Nutrition in the World estimates that between 720 and 811 million people were affected by hunger in 2020, up to 161 million more than in 2019, with the outbreak by the COVID-19 crisis.

Furthermore, FAO [2] indicates that agriculture over the world would face substantial challenges in terms of supplying food to feed the world population. The world now faced the development of food insecurity and the food crisis is most often associated with rural areas [3] with heterogeneity and variation within and between global food security indicators [4]. Mohammadi et al. [5] confirm that the most food security challenges and barriers such as direct policy deficiencies and institutional constraints and the three dimensions of food security (utilization, agency, and sustainability) are mainly ignored [5].

Briefly looking at the GCC countries, during the last era, the GCC countries intended to outsource agricultural production using two ways: importing food and acquiring land abroad to fill a gap in the food supply [6].

The GCC governments have been active in addressing the threat of food security and over the past decades, despite a significant development in economic growth in the GCC countries, food security is one of the most targeted agendas of GCC countries. Nowadays, food security has recently become a priority for the GCC governments which is involved in their national strategic plans, and has become increasingly significant to the political agenda in GCC countries, for instance, the Saudi Vision 2030 and the United Arab Emirates' future possibilities [7; 8].

For eradicating the problem of food security, the GCC countries are seeking to be sufficient in food production and increase food stock for a population to meet their daily requirements through international investment. The main reason behind the GCC engaging in international investments, because that most of the GCC have faced several challenges encounters and hinder food security.

Increasing population is a key strategic challenge for the GCC countries. Alharthi [9] investigates that population growth in the GCC countries affected the economies significantly and adversely. The GCC countries have rapidly expanded GCC populations as a result of the large foreign migrant workforce. The Migrants constitute a substantial share of percentages of the GCC population, estimated as most share (88 %) in UAE; (76 %) in Qatar; (74 %) in Kuwait; (51 %) in Bahrain, and (41 %) in Oman, whereas it constitutes the least share (32 %) in Saudi Arabia [10]. Moreover, the decline in agriculture production is attributed to decreasing and scarcity of natural resources (e.g., scarcity of water and shortage of farmland) which poses a natural challenge to food security in GCC countries. Across the coming decades, economic crisis and climate change will have significant but uncertain influences on food security for instance fluctuations in the food price can directly affect food affordability [11].

As shown in Figure 1, over 2020 the rapid food prices inflation is noted in the GCC countries between April – December specifically in Saudi Arabia, which reached a peak in July. Kuwait shows the growth of increasing food price inflation between August and December, in contrast, Oman observed low food price inflation during the same periods. While the United Arab Emirates and Bahrain show variation in the food prices inflation.

The rationale for studying this research is that: based on the estimation of the Economist Intelligence Unit [13] it is stated that the GCC countries are food secure in comparison with other world countries; Hassen and El Bilali [14], reveal that the food security problems of the GCC are more likely to be related to food self-insufficiency rather than food insecurity. Despite the improvement of the food security index (FSI) score of some countries (Kuwait, Oman, and Bahrain) in 2020, globally, the rank of the GCC countries based on the overall food security environment across all countries deteriorated in 2020 in comparison with 2018.

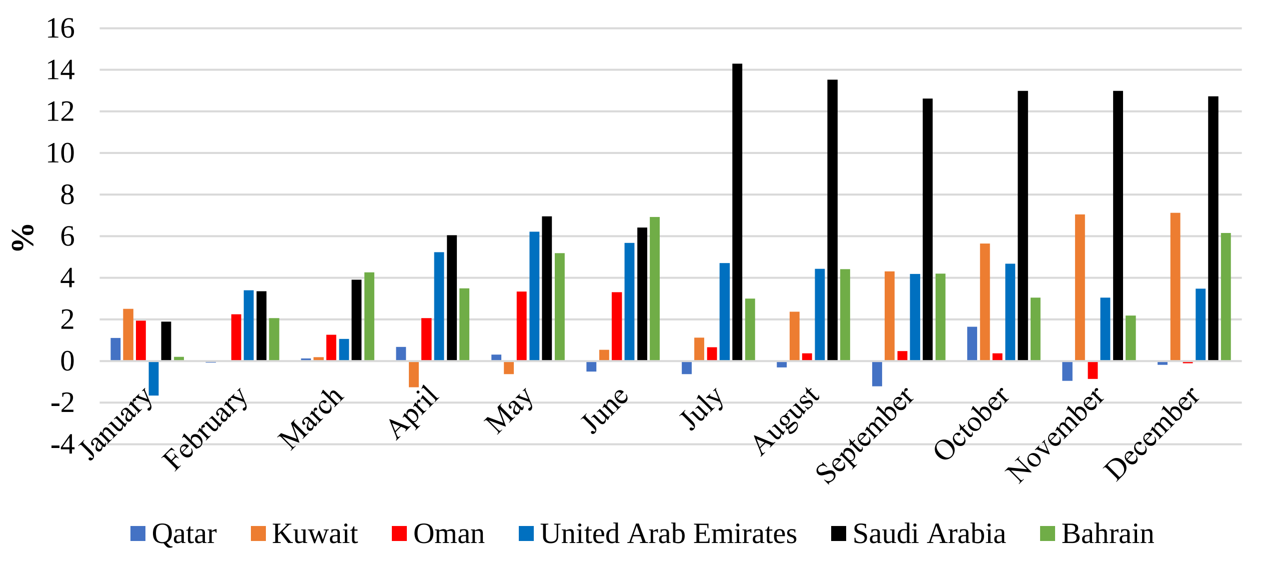

Figure 1. Food price inflation among the GCC countries across 2020, %

Source: developed by the author according to FAOSTAT data [12].

FSI is slightly declined in descending order in Saudi Arabi (-0.7), UAE (-1.9), and Qatar (-2.1), while the marked improved score in Kuwait (+1.5) and Oman and Bahrain is estimated by an equal improved score (+1.1) for each (Table 1).

Table 1

Ranking of GCC countries in the global FSI (2018–2020)

GCC countries	Rank in 2018	Rank in 2020	Food Score in 2020*	Change in food score	Improved / worsened
Qatar	22	37	69.6	-2.1	worsened
Kuwait	28	33	70.7	+1.5	improved
Oman	29	34	70.2	+1.1	improved
UAE	31	42	68.3	-1.9	worsened
Saudi Arabia	32	38	69.5	-0.7	worsened
Bahrain	41	49	64.6	+1.1	improved

Note. *Scores are standardized 0–100, where 100 = Most favorable food security environment.

Source: developed by the author according to Economist Intelligence Unit [13].

Moreover, based on the dataset formulated by the Economist Intelligence Unit [13], the performance of the GCC countries based on their FSI scores seems to improve across Bahrain, Oman, and Kuwait but shows a slight decline in Saudi Arabia, UAE, and Qatar in the year 2020 compared to the year 2012 (Figure 2). The overall mean of FSI across 2012–2020 is 66.8 with a minimum and maximum of 58.4 and 71.7 respectively.

Oil and natural gas return still constitute the key part of the national income in GCC countries. GCC countries face several conservation challenges and will have to resolve the many contradictory priorities aspects such as water scarcity, food security, desertification, economic diversification, and resources management to the impacts of climate change. Thus, this study will deliver a better understanding of food security challenges in GCC countries, which will help in forming policy strategies in the present and future time.

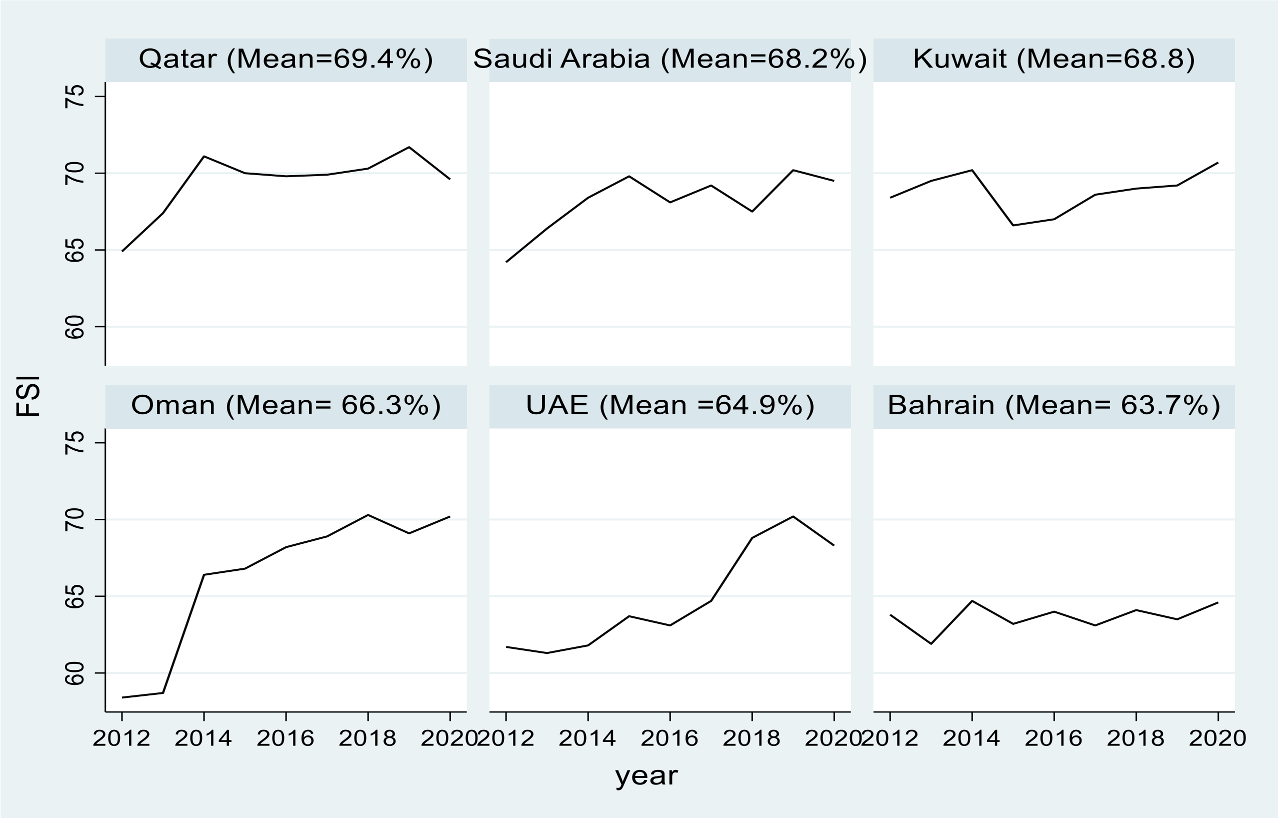

Figure 2. Performance of the GCC States based on their FSI (2012–2020)

Source: developed by the author according to Economist Intelligence Unit [13], graphs by ID.

Currently, there are still research gaps in the original research published on the challenges of the food security indicators aspects conducted in GCC countries. Limited numbers of the studies have examined the determinates of food security using the econometrics models [15], besides, the keywords for some previous and existing studies of food security, directly or indirectly achieved in GCC countries, were addressing aspects related to strategies, water, agriculture, tourism, food production, energy, and sustainable development [16–19].

Considering the implications of food security mentioned above in GCC countries, this study tries to fill a gap in investigating the combination of the food security challenges illustrating the effects of each challenge on the food security indicators.

This article consists of the following four sections. The first section covers the introduction and the related literature. The second section presents the material and methods. The third section interprets the results and discussions. Whereas the last section draws the study's conclusions and makes some policy recommendations to overcome the current and future food security challenges that faced the GCC countries.

It is well known that food security is a complex and multidimensional concept that can be assessed by various indicators. Usually, food security involves the four pillars or indicators, categorized as the availability, access, utilization, and stability of food [20]. Numerous studies have depicted the significant role of analyzing the food security indicators and challenges among the various world nations [21; 22]. Most the scholars identified the most effective challenges that threaten food security as the fast expansion of the population growth, increasing of malnutrition and hunger; scarcity of water, scarcity of mineral and trace elements; changes in global climate patterns, changes in land-use patterns; changing in food behaviors; deteriorating of the crops land and diminishing in crops production; undernourishment; economics crisis, change in markets conditions, political instabilities, and recently the spread out of the virus diseases [23–25]. Moreover, Badghan et al. [26], confirm that the food security challenges can similarly be constructed in the manner of qualitative challenges.

Population growth is the greatest social challenge facing food security worldwide, hence population growth will greatly increase the amount of food needed to adequately feed people. Population growth affects the reduction in food production indirectly, for instance, during the peak population period, the irrigation water demand will increase [27], and the countries like GCC which are suffered from water scarcity which is one of the important prerequisites for increasing crop yield and hence insuring and filling the domestic food shortages.

In the Middle East, food insecurity is exacerbated by rapid population growth, and the population growth combined with other factors such as: urbanization, climate change, and reduced yield of crops have resulted in increased global food demand [28; 29]. A recent study [30] examines the projected different population changes and confirms that countries with a predicted decline in population growth had higher food security, while those with a predicted rapid population growth tended to suffer the worst shocks in food security, in addition the study shows that population growth and land-use change could have the greatest impact on the food security. Furthermore, Blekking et al. [31] investigate the connection between food security and different employment types by performing the Food Consumption Score (FCS) and the Coping Strategies Index (CSI) measures using ordinary least squares (OLS) regression and their results reveal that the effect of employment on predicting FCS and CSI is not the same.

Studies rely on various proxies that capture diverse aspects of the social challenges of food security such as the dietary shift/change, the changes in food habits as well as life satisfaction [32–34]. Meanwhile, Salahodjaev and Mirziyoyeva [35] study the causal link between food security and life satisfaction worldwide using panel data analyzed by conventional OLS regression and instrumental variable two-stage least squares (IV2LS) method and find that food insecurity is significantly and negatively correlated to life satisfaction.

Despite the reliance of previous studies on investigating the social challenges of food security, several researchers have studied the most economic challenges of food security correlated to goals and sites of searches from the economic view and lastly agreed that growth of the economy can have a significant positive impact on food security. Gödecke et al. [36] use the cross-country panel data regressions estimating the fixed effect (FE) and random effect (RE) to indicate that higher per capita gross domestic product (GDP) is strongly associated with a lower burden of chronic and famine. Newly, an opinion-based article conducted during the COVID-19 era (2019/2020) shows that the main challenges to food security in Pakistan during a pandemic are the consumer prices index and food inflation price [37].

Molotoks et al. [30] prove that climate change is a key driver of severe food crises. In the other context, the food security trends are likely to have a negative significant challenge by climate change in developed countries as well as in developing countries unfavorable climatic conditions adversely affect the household's food security [38]. Many factors of climate change can challenge food security directly through changes in agroecological conditions the aggravating the greenhouses gases (GHG) emissions intensity breaking the balance of food security and ecosystem sustainability [39] and indirectly through affecting economic growth and allocation of incomes and thus demand of agricultural products [40].

A previous study [41] using the panel data generating a time-variant household food security index which is created by principal components analysis confirms that the level and variability of rainfall significantly affect food insecurity. Correspondingly, Wang [42] applies the balanced panel data analysis by pooled ordinary least square (POLS), Fixed Effect (FE), difference Generalized Method of Moments (DIF-GMM), and system GMM (SYS-GMM) to estimate the effect of the climate change on the food security and confirm that climate change affects the food security.

The lack of sustainable agriculture development is the main factor threatening food security in term of the overuse of fertilizers, Xin and Tao [43] examine structural equation modeling (SEM), for determining the main factors that lead to the climate change and confirm that the fertilizer consumption played dominate role in increasing the carbon dioxide emissions. But in the same way, the use of fertilizers increases crop production and enhances food security. Similarly, a study done by Chandio et al. [44] using a panel cointegration approach, finds that consumption of fertilizers has a positive impact on rice production.

We concluded that from the previous literature review, most articles are primarily oriented toward examining the food security challenges from one separate aspect, economics, climate, or social aspects.

The purpose of the article. Against this background, the purpose of this article is to identify the challenges of food security across the GCC countries for the period 2000–2020 focusing on the major challenges facing food security given economic, climate, and social challenges. Besides the study attempts to explore the most appropriate model of the econometric approach for achieving the goal of the study. Likewise, the current study considers the issue of research as: what is the biggest challenge that affects food security significantly?

Methodology. The six GCC countries selected as the study area, named as Saudi Arabia, Area United Arab Emirates (UAE), Bahrain, Kuwait, Oman, and Qatar. The willingness for selecting the GCC countries as the study area since the GCC countries share identical climatic conditions, characterized by desert geographies, and marked by high temperature and limited rainfall, besides, the economic situation of the GCC countries is homogeneous (oil countries). Additionally, the food habits are nearly similar in the GCC countries. The GCC countries lie at longitude from 45 to 58◦E and latitudes from 20 to 30◦N [45]. The total area of the GCC countries is 2 557 470 km^2 (Saudi Arabia occupies the greatest percentage (85.0 %) with a total population of over 56 million in 2019 [46].

The dataset of this study includes the annual secondary data covering the time 2000–2019 of the six GCC countries. The purpose for selecting the time frame of data is that secondary food security data by FAO is available only for this period and through this era the Global financial crisis takes place (2007–2009). Additionally, most of the GCC countries issued significant visions and future possibilities in (2016–2019) considering the food security aspects as well.

The dependents variables represent the food security indicators whereas, the independents variables (explanatory) represent the challenging factors of the food security at the macro-level data.

The food security indicator dataset incorporated in this study is derived from the FAO suite of Food security indicators [12], which involves 4 indicators categorized as average value of food production (AFP), gross domestic product (GDP), food imports (VOFI), and obesity (POB) along the four dimensions of food availability, access, stability, and utilization, respectively. The reason behind selecting such dependents variables is that: for example, the percentage of the prevalence of obesity in the adult population is high among the GCC countries.

Further, the data of the explanatory variables have been retrieved from the World Bank statistics [47]. The explanatory variables include the (1) annual population (POP), which represents the social factor; (2) food price inflation (FPI) represents the economic factor, and (3) fertilizers consumption (FC) represents the agri-environmental factors. We selected such explanatory variables because these variables from the literature review are the most factors that influence food security.

All the studied variables are reshaped in the balanced panel form; thus, the study uses a long panel, it has many periods (large T, 20 years) but few entities (n = 6 countries of GCC) with the total observation, $N = n \cdot T = 120$. Table 2 presents the explanation of the key terms, measuring unit, and descriptions of the main variables (types of the variables).

Table 3 shows the statistics summary of the studied variables. Regarding the food security indicators: The overall average value of food production is (59279.94 USD) ranging from 27896.30 USD (minimum) to 104091 USD (maximum). The overall mean of GDP per capita is (83.88 USD per capita) with the highest (247 USD per capita) and lowest (21 USD per capita). The highest percentage of the food import is (10.0 %) with the lowest percentage (2.0 %) during the studied period with an overall mean (4.6 %). The overall percentage of the prevalence of obesity is (28.2 %) with the lowest percentages (18.0 %) and highest percentages (37.9 %).

Moreover, concerning food security challenges: the largest population over the study period was observed in Saudi Arabia in 2018 and is estimated at 33702.76 thsd persons, while the smallest population was observed in Qatar in 2000, it was estimated at 592.49 thsd persons.

Table 2

Clarification of key terms used in the study

Variable	Explanation	Unit of measure	Type of food security indicators / challenges
Dependent variables			
AFP	The average value of food production (constant 2004–2006) for a 3-year average	USD	Availability
GDP	Gross domestic product per capita, PPP, dissemination "constant 2011"	USD per capita	Access
VOFI	Value of food imports in total merchandise exports (3-year average)	%	Stability
Explanatory variables (independent variables)			
POB	Prevalence of obesity in the adult population (18 years and older)	%	Utilization
POPU	Annual population	1000 persons	Social factor
FC	Fertilizer consumption: measures the amount of plant nutrients used per unit of arable land	kg/ha	Agri-environmental factor
FPI	Food price inflation, annual consumer prices	%	Economic factor

Source: designed by author.

Table 3

Statistical summary of the cross-country original panel variables.

Variable		Mean	Std. dev.	Min	Max	Observations
AFP	Overall	59279.94	22669.31	27896.30	104091.00	N = 120
	Between	-	23225.62	32159.28	96145.88	n = 6
	Within	-	7784.32	39330.25	86903.45	T = 20
GDP	Overall	83.88	44.74	21.00	247.00	N = 120
	Between	-	42.78	25.93	123.13	n = 6
	Within	-	21.54	21.56	222.56	T = 20
VOFI	Overall	4.59	1.75	2.00	10.00	N = 120
	Between	-	1.46	2.38	6.00	n = 6
	Within	-	1.13	1.60	8.72	T = 20
POB	Overall	28.19	4.39	18.00	37.90	N = 120
	Between	-	2.93	23.53	31.54	n = 6
	Within	-	3.48	14.64	34.54	T = 20
POPU	Overall	7130.15	9311.20	592.47	33702.76	N = 120
	Between	-	9920.87	1116.86	26950.35	n = 6
	Within	-	1997.34	843.64	13882.55	T = 20
FPI	Overall	2.50	3.11	-0.86	15.05	N = 120
	Between	-	0.65	10.76	3.46	n = 6
	Within	-	0.05	-0.82	14.09	T = 20
FC	Overall	586.47	673.23	38.46	3100.73	N = 120
	Between	-	567.41	88.64	1638.10	n = 6
	Within	-	427.42	-01.63	2049.10	T = 20

Source: author's computations based on the studied data.

The highest percentages of food price inflation were observed in Qatar in 2008 with the average percentages across all countries (2.5 %). Furthermore, from Table 3, it seems that the average quantities of the fertilizer's consumption overall in all the countries are (586.47 kg/ha) with the lowest quantities consumed during 2000 estimated as (38.46 kg/ha) and the highest quantities consumed during 2011 noted in Bahrain and estimates as (3100.73 kg/ha).

The standard deviation for population, fertilizers consumption, and food price inflation is greater than the average value (corresponding mean) indicating that might be present of the non-normality distribution of data in (population and fertilizers consumption) and the negative numbers in food price inflation.

Empirical econometric techniques. This study applies the balanced panel regression model grouped into four sub-panels food security models parallel to the food security indicators. The data was analyzed by pooled ordinary least square (POLS), fixed effect (FE), and random effect (RE) regression models to examine the relationship between the food security indicators and population, food price inflation, and fertilizers consumption. The models were run separately for each food security indicator (AFP, GDP, VOFI, and POB).

To verify which model (POLS, FE and RE) was the most appropriate, the F-statistic, Lagrange Multiplier (LM) developed by Breusch and Pagan [48], and Hausman test [49] were performed. We approved these approaches of analysis, for the reasons: firstly, it is more suitable for the number of the period (T) < 25 and the numbers of countries (n) < 25, since small T panel estimation usually relies on fixed-or random-effects estimators or a combination of fixed-effects estimators and instrumental-variable estimators [50]. Secondly, it is suitable when there is a presence of unit root among the food security indicators. Thirdly, it depicts heterogeneity effects in the data as we have some noted challenging factors due to cross-sectional differences among the countries.

Basic econometric tests. Before starting the process of modeling the data, significant statistical tests were performed, for instance: to estimate whether there is a relationship between food security indicators and challenging factors, the Pearson Product-Moment Correlation approach (PPMC) together with multi-collinearity test via tolerance and Variance Inflation Factor (VIF) approaches, is used to detect and avoid the severity of multicollinearity among the explanatory variables in the OLS regression analysis. Likewise, skewness / kurtosis and Jarque and Bera [51] tests for normality of residuals are verified. Furthermore, homogeneity and cross-sectional dependence (CD) preliminary tests are performed following Pesaran et al. [52].

Unit root tests. A plot graph is built to visualize the food security indicators and challenges variables and to compare their trend with one another in the selected period. But it is difficult to assess the condition of the stationary characteristics of these panel data based on plots. As we are interested in whether the studied variables (food security indicators and challenges factors) are stationary or not, thus, the current study applies two statistical unit root tests for examining the stationary characters following:

A. Levin-Lin-Chu (LLC) test. The model of the LLC test is an expansion of the Augmented Dickey-Fuller, ADF [53; 54] test in the context of panel data since the LLC test proposes that individual processes are cross-sectionally independent, so we adopt that the LLC test equation for Y_{it} is generated by the following form:

$$\Delta Y_{it} = \alpha_i + \emptyset_i + \delta t_i + \rho_i Y_{i,t-1} + \sum_{K=1}^{n} \emptyset_K \Delta Y_{i,t-K} + \mathcal{U}_{it}. \quad (1)$$

The LLC equations include two fixed effects, α_i and $\emptyset_i$ (unit-specific time effects), furthermore, the LLC test comprised separated deterministic trends in each series though δt_i and the lag form $(\Delta Y_{i,t-K})$ for removing the autocorrelation in ΔY_{it}. According to the log order (ρ_i) for each cross-section, the H_0 and H_1 of the LLC test can be written as follows:

$$H_0 : \rho_{i=} \rho = 0, \quad (2)$$
$$H_1 : \rho_{i=} \rho < 0, for\ all\ i = 1, \dots . N. \quad (3)$$

This test was approved for this study because is likely to be suitable in a small sample of the time trend.

B. Breitung and Das unit root test. Breitung and Das [55] suggest a robust OLS statistic involving panel corrected standard errors and establish the equation in matrix form, i.e., the cross-sectional correlation is depicted by a non-diagonal covariance matrix (Ω) and present the data such as:

$$\widetilde{y_{ti}} = y_{ti} - y_{0i}, \quad (4)$$

where y_{0i} is the value of the initial observation and regularly estimates the variance-covariance matrix of the OLS estimator which denotes by $\hat{\vartheta}_{\hat{\beta}}$, later the robust t-statistic free of size distortions due to contemporaneous cross-sectional correlation for N and T tending to infinity achieved [56].

$$t_{rob} = \frac{\hat{\beta}}{\sqrt{\hat{\vartheta}_{\hat{\beta}}}} = \frac{\sum_{t=1}^{T} y'_{t=1} \Delta y_t}{\sqrt{\sum_{t=1}^{T} y'_{t=1} \hat{\Omega} y_t}}, \quad (5)$$

Moreover, Werkmann [57] indicates that for a weak cross-sectional correlation, Breitung and Das test displays that t_{rob} has a standard normal limiting distribution in the null hypothesis:

$$t_{rob} \overset{d}{\to} N(0.1), as\ T \to \infty, folowed\ by\ N \to \infty \quad (6)$$

This test has been chosen to be used in this study, because the method does not depend on the frequency of the weight function and is suitable for a small sample study test based on residual, in our study the T is greater than n.

POLS model. POLS is also known as the Constant Coefficient Model (CCM), this model assumes that if an individual effect μ_i (cross-sectional or time-specific effect) does not exist ($\mu_i = 0$), OLS produces efficient and consistent parameter estimates (efficient model). In our study the equation of POLS for food security equation takes the formula as follows:

$$FSI_{it} = \alpha_i + \beta FC'_{it} + \mathcal{U}_{it},\ \text{i} = 1 \dots\dots \text{N and t} = 1, \dots\dots\dots \text{T} (\mu_i = 0), \quad (7)$$

where FSI_{it} denotes the dependents variables (food security indicators), in this study the dependents variables as mentioned briefly in (Table 2) are AFP, GDP, VOFI, or POB;

FC'_{it} is a set of the explanatory variables (challenges) i.e., including the ith observation of K on explanatory variables, POPU, FC, or FPI;

β_{it} has estimated coefficients for POPU, FC, or FPI;

i denotes GCC countries (1 to 6) and t denotes time (2000 to 2019), the i and t subscript, thus denote the cross-section dimension and time-series dimension, respectively;

α_i is a fixed effect (scalar), denotes unobserved country-specific effects which are assumed to be fixed over time and vary across countries (i);

$\mathcal{U}_{it}$ random disturbance, while most of the panel data presentations employ a one-way error component model for the disturbances with:

$$\mathcal{U}_{it} = \mu_i + \mathcal{V}_{it}, \quad (8)$$

where μ_i denotes the unobservable individual-specific effect and ν_{it} denotes the residue disturbance [58].

FE model. A fixed-effect model examines if intercepts vary across groups or time [59]. FE model is estimated by least squares dummy variable (LSDV) regression (robust model). A parameter estimate of a dummy variable is a part of the intercept (α_i) in a fixed-effect model, i.e., the intercept is varying across groups and/or time. Thus, the equation of FE for food security indicators takes the follows:

$$FSI_{it} = (\alpha_i + \mu_i) + \beta FC'_{it} + \mathcal{V}_{it}. \quad (9)$$

In this fixed-effect regression model, the null hypothesis (H_0) is that all dummy parameters are equal to zero exclusion for omitted one.

$H_0 = \mu_1 - - - \mu_{1-1} = 0$, while the alternative hypothesis (H_0), is that at least one dummy parameter is not zero.

$H_1 \neq 0$, if the H_0 is rejected there is a significant FE. For selecting whether the EF is better or not than the POLS, then this hypothesis is tested by the F-statistic test.

The F-statistic test contrasts LSDV with the POLS model and examines the extent that which the goodness-of-fit measures (R^2) changed and takes the formula of:

$$F(n-1, nT-n-K) = \frac{(\acute{e}\, e_{pooled} - \acute{e}e_{LSDV})/(n-1)}{(\acute{e}e_{LSDV})/(nT-n-K)} = \frac{R^2_{LSDV} - R^2_{pooled}\ /(n-1)}{1-R^2_{LSDV}/nT-n-K)}, \quad (10)$$

where $\acute{e}\, e_{pooled}$ *and* $\acute{e}e_{LSDV}$ is the sum of squares due to the error of the POLS and LSDV model;

T is the number of periods (T = 20 years).

The null hypothesis (H_0): select POLS (P > 0.05) otherwise the alternative hypothesis (H_1): select FE (P < 0.05).

RE model. A random-effect model explores differences in error variance components across individuals or time. A parameter estimate of a dummy variable is an error component in a random effect model, i.e., the intercept ($\propto_i$) is constant. Thus, RE formulas for the food security indicators take the follows:

$$FSI_{it} = \alpha_i + \beta FC'_{it} + (\mu_i + \mathcal{V}_{it}). \quad (11)$$

The RE model is tested by the Lagrange multiplier (LM) statistic test and it follows the chi-squared (X^2). The LM test investigates if individual or period-specific variance components are zero, then:

$$H_0 = \sigma_u^2 = 0, \quad (12)$$

where σ_u^2 is variance components estimated in RE in case the H_0 is rejected, there is a significant RE in the panel data, the advantage of the RE is that it is well consistent with heterogeneity than does the POLS. The LM takes the formula as:

$$LM_u = \frac{nT}{2(T-1)}\left[\frac{T^2\bar{\acute{e}}\,\bar{e}}{e^{\prime}e} - 1\right]^2 \sim X^2, \qquad (13)$$

where $\bar{\acute{e}}\,\bar{e}$ is the sum of squared means group-specific residuals.

H_0: select POLS (P > 0.05) otherwise H_1: select RE (P < 0.05).

Furthermore, the specification test developed by Hausman [42] is applied to test for orthogonality of the RE and the regressors. The test is founded on the concept that under the hypothesis of no correlation, both OLS in the FE model and RE are consistent, but OLS is inefficient, whereas, under the alternative, OLS is consistent, but RE is not [60]. Therefore, the Hausman test performs for comparing the relevance of the FE and RE models and takes the formula:

$$H = (\beta_{FE} - \beta_{RE})^{\prime}\left[Var\,(\beta_{FE}) - Var(\beta_r)\right]^{-1}(\beta_{FE} - \beta_{RE}), \qquad (14)$$

where H denotes to Hausman test, β_{FE} which is the coefficient of FE and the coefficient of β_{RE}.

H_0: select RE (P > 0.05) otherwise H_1: select FE (P < 0.05).

Results and discussion. *Basic econometrics tests results.* Table 4 summarizes the result of PPMC and VIF results. The PPMC results indicate that food production has a statistically significant and negative correlation with GDP, food import, population, and fertilizers consumption, however, has an appositive correlation with obesity and food price inflation. Besides, GDP, and food imports, show a negative correlation with obesity and a positive correlation within the population. However, GDP does not correlate with food import and food price inflation, but a negative correlation and statistically significant is identified between GDP and fertilizers consumption, though, food import correlated positively with fertilizers consumption. Likewise, obesity and population have shown a negative correlation between fertilizers consumption. It noted that fertilizers consumption has a statistically significant correlation with all variables except food price inflation. As the evidence of highly correlated variables can affect the precise estimation of regression which might lead to bias inference [61], the study achieves a multi-collinearity protection omission or inclusion of explanatory variables within the study model.

Table 4

Pearson correlation coefficient and multicollinearity analysis

PPMC Results								Test of multi-collinearity	
Variable	AFP	GDP	VOFI	POB	POPU	FPI	FC	VIF	Tolerance
AFP	1							-	-
GDP	-0.26***	1						-	-
VOFI	-0.71***	0.18	1					-	-
POB	0.31***	-0.23**	-0.46***	1				-	-
POPU	-0.27***	0.44***	0.22**	0.14	1			1.12	0.89
FPI	0.22**	-0.11	-0.25***	0.20**	-0.02	1		1.01	0.99
FC	-0.21**	-0.36***	0.30***	-0.21**	-0.33***	-0.09	1	1.13	0.88
Mean VIF = 1.09									

Note. ***, **, and * represent statistical significance at the 1 %, 5 %, and 10 % level, respectively.
Source: author's computation based on the collected data.

The tested values of VIF are lower than 2 and the results of mean VIF are less than 5 (1.09), beside the degree of tolerance for explanatory variables is greater than 0.5 (Table 4) suggesting that there is no multicollinearity between the explanatory variables, so the population, fertilizers consumption and food prices inflation are included in the study models as social, agri-environmental, and economic keys challenges are affected the food security indicators in GCC countries.

Moreover, Table 5a shows that the food security indicators for GDP and obesity are positively skewed across all panels with p > 0.05, which indicates that these indicators are normally distributed. Whereas the other indicators (food production and food import) together with all food security challenges (population, food price inflation, and fertilizers consumption) show non-normal distributions. Accordingly, the variables are transformed into logarithmic forms.

Table 5a

Skewness / Kurtosis tests for normality

Variable	Obs	Pr (skewness)	Pr (kurtosis)	adj chi2(2)	Prob>chi2	Normality
AFP	120	0.00	0.00	15.36***	0.00	Non-normal
GDP	120	0.21	0.99	1.59	0.45	Normal
VOFI	120	0.00	0.50	6.89**	0.03	Non-normal
POB	120	0.59	0.35	1.16	0.55	Normal
POPU	120	0.00	0.01	31.01***	0.00	Non-normal
FPI	120	0.00	0.00	55.31***	0.00	Non-normal
FC	120	0.00	0.00	44.63***	0.00	Non-normal
Jarque-Bera Test for Normality of Residuals (Joint test)						
JB test	120	0.7061	0.0684	3.54	0.1702	Normal

Note. ***, **, and * represent statistical significance at the 1 %, 5 %, and 10 % level, respectively.

Source: author's computation.

Besides, the JB normality jointed test assures the normality of errors at a 5 % significance level i.e., given that the p-value (0.1702) is greater than 5 % for the residual, the H_0 is accepted and thus the residuals are normally distributed (Table 5a).

Furthermore, our empirical results for slope homogeneity are reported in Table 5b indicating the rejection of the null hypothesis and acceptance of the alternative hypothesis of the heterogeneity at 1 % for the dependents variable for AFP and GDP variables. However, the results show that the slope coefficient of the VOFI is homogenous.

Table 5b

Testing for slope heterogeneity

Dependent variable	AFP		GDP		VOFI	
Test	Statistics	p-value	Statistics	p-value	Statistics	p-value
Delta	6.66 ***	0.00	3.04***	0.00	0.75	0.45
Delta adj.	7.96 ***	0.00	3.64***	0.00	0.90	0.36

Note. ***The level of significance is determined by 1 %.

Source: author's computation.

Table 5c displays the findings of the CD test created on the results of the cross-sectional dependence attempt, the rejection of the null assumption, and acceptance of the alternative statement that, a cross-sectional dependence exists within variables for VOFI, POB, POPU, and FC was crucial at the 1 % level. While our results show no existence of a cross-sectional dependence within variables for AFP and GDP.

Table 5c

Results of cross-sectional dependence test

Variable	CD-test	p-value
AFP	0.86	0.39
GDP	0.55	0.58
VOFI	8.44***	0.39
POB	6.99***	0.00
POPU	16.68***	0.00
FC	2.36***	0.00

Note. ***The level of significance is determined by 1 %.

Source: author's computation.

Unit root test result. The LLC and Breitung test results are reported in Table 6. The results reveal that Log AFP, Log VOFI, Log POPU, Log FPI, and Log FC variables are stationary (no unit root) at the level test and therefore are said to be stationary and integrated of order zero i.e. I (0). While GDP, POB, and Log FPI are non-stationary at the level test (unit root) and this means that all of the variables have the same order of integration, which is I (1), and further became stationary at the first-order difference (Table 6). In contrast, the Breitung test shows that the VOFI, FC, and FPI variables are stationary at level, while the AFP, GDP, POB, and POPU become stationary at the first-order differences.

Table 6

LLC test for unit root at the level

Unit root analysis at the level						
Variable term	LLC t-statistic	p-value	Statistical decision	Breitung lambda	p-value	Statistical decision
Log AFP	-1.61**	0.05	S	0.08	0.52	NS
GDP	-1.29*	0.09	NS	0.01	0.50	NS
Log VOFI	-2.07**	0.01	S	-2.56***	0.00	S
POB	-0.30	0.38	NS	2.13	0.98	NS
Log POPU	-1.82**	0.03	S	0.42	0.66	NS
Log FC	-3.39 ***	0.00	S	-1.70**	0.04	S
Log FPI	-1.13	0.12	NS	-4.47***	0.00	S
Unit root analysis at first difference						
Δ Log AFP	-	-	-	-3.98***	0.00	S
Δ GDP	-2.52***	0.00	S	-2.17**	0.01	S
Δ POB	-3.84***	0.00	S	-7.09***	0.00	S
Δ Log POPU	-	-	-	-1.80**	0.03	S
Δ Lag FPI	-4.62***	0.00	S	-	-	-

Notes. S = stationary, NS= non-stationary, Δ Stands for the first difference.
***, **, and * represent statistical significance at the 1 %, 5 %, and 10 % level, respectively.
Source: author's computations.

Challenges of the Food security indicators. The estimations observed from Table 7 show that the influence of the population has a negative influence on food availability as expected, moreover, fertilizers consumption negatively impacts food availability. However, the population impact of food availability is stronger than fertilizer consumption. This result confirmed by Molotoks et al. [30] that population growth affects food availability. In contrast with Arabic countries, Devesh and Affendi [15], find that food security is significantly affected by the population growth rate in Oman, and rising population growth positively influences food security in Algeria [62].

While food price inflation has a positive impact on food availability. These results confirmed with [63] argued that an increase in food prices will adversely affect food availability. In comparing the F-statistic, $p < 0.05$, then the FE model is recommended over the POLS. However, the Breusch-Pagan LM test indicates that the POLS method became preferable over the random-effects model, $p < 0.05$ (Table 7). Conversely, the Hausman test accepted the null hypothesis, therefore, the Hausman test indicated that the studied variables were correlated and indicate that the RE method became preferable to the FE model ($p > 0.05$). Later, as the results of the tests' analysis, the RE was chosen. The choice of this model was proven after the results of the F-statistic, Breusch-Pagan LM and Hausman, used to determine which model was most appropriate (Table 7).

Table 7

Challenges of food availability in the GCC countries (2000–2020)

Model	Estimators			
	POLS (CCM) (t-value)	FE (LSDV) (t-value)	RE (GLS) (Z-value)	Difference (FE-RE)
Constant	5.40*** (35.67)	5.23*** (51.83)	5.23*** (39.10)	-
Δ log POPU	-0.12*** (-3.85)	-0.14*** (-4.55)	-0.14*** (-4.59)	0.00
Log FC	-0.10*** (-3.46)	0.01 (0.03)	-0.00 (-0.04)	0.00
Δ Lag FPI	0.055 (0.12)	0.03** (2.78)	0.03*** (2.82)	0.00
R^2	0.16	-	-	-
F-statistic (Prob > F)	7.47*** (0.00)	9.98*** (0.00)	-	-
F test that all u_i=0:	-	242.66*** (0.00)	-	-
Wald chi2(3) (Prob > chi2)	-	-	30.58** (0.00)	-
LM (Prob > chibar2)	-	-	870.11*** (0.00)	-
Hausman: chi2(3) (Prob>chi2)	-	-	-	0.17 (0.98)

Notes. (i) t and z-statistics are reported in parentheses; (ii) ***, **, and *represent statistical significance at the 1 %, 5 %, and 10 % level, respectively.

Source: panel models' results.

Additional findings, the results in Table 8 confirm the study hypothesis that the population factor challenges food access. However, the first-year lag of the population is positive in the POLS estimation but negative in the fixed-effect model. The coefficient and the significance levels also differ between the models for other variables. The fixed-effect model examines with positive significantly coefficient of FC. Boulanger et al. [64], indicate that the use of fertilizers enhanced food security (food availability). The result for food price inflation is more uncertain, with a statistically not significant coefficient in the three estimations.

Additionally, Table 8 shows the p-value of the tests at a significance level of 1 % given that Ho was rejected through the F-test result (0.00). Therefore, we concluded that the FE model was an adequate option, moreover, the Hausman test rejected the null hypothesis such as the Breusch-Pagan LM test; therefore, the Hausman test indicates that the variables were uncorrelated ($p < 0.05$).

Table 8

Challenges of food access in the GCC countries (2000–2020)

Model	Estimators			
	POLS (CCM) (t-value)	FE (LSDV) (t-value)	RE (GLS) (Z-value)	Difference (FE-RE)
Constant	-110.56** (-3.05)	349.77*** (8.10)	224.51	-
Δ log POPU	55.30*** (7.57)	-84.67*** (-6.45)	-40.68	-43.20
Log FC	0.45 (0.06)	14.61* (2.06)	1.85	12.76
Δ Lag FPI	-10.92 (-1.31)	-0.18 (-0.04)	-1.12	0.94
R^2	0.36	0.34	0.35	-
F-statistic (Prob > F)	21.68*** (0.00)	14.01*** (0.00)	-	-
F test that all u_i = 0:	-	60.93*** (0.00)	-	-
Wald chi2(3) (Prob > chi2)	-	-	10.95 (0.01)	-
LM (Prob > chibar2)	-	-	188.02*** (0.00)	-
Hausman: chi2(3) (Prob>chi2)	-	-	-	110.72*** (0.00)

Notes. (i) t and z-statistics are reported in parentheses; (ii) ***, **, and * represent statistical significance at the 1 %, 5 %, and 10 % level, respectively.

Source: panel models' results.

At the same time, the Breusch-Pagan test indicates that the FE method became preferable to the pooled and random-effects model. This indicates that there is evidence of significant differences in food access across the GCC countries (Table 8).

Concerning food stability, as is expected the results of the three models indicate that the increase in the total population will lead to an increase in food import (food stability) positively (Table 9). This result is consistent with Xiang et al. [65], which indicates that the high population pressure has increased the imported food to meet the food security. Besides, the study results indicate that food price inflation has a significant negative impact on the food import (food stability), these results are consistent with Wardhani and Haryanto [66], who confirm that food price inflation has shown a negative effect on food security (Table 9).

Table 9

Challenges of food stability in the GCC countries (2000–2020)

Model	Estimators			
	POLS (CCM) (t-value)	FE (LSDV) (t-value)	RE (GLS) (Z-value)	Difference (FE-RE)
Constant	-0.05 (-0.35)	0.33* (2.22)	0.32 (1.96)	-
Δ log POPU	0.11*** (3.46)	0.07* (2.12)	0.07* (2.18)	0.00
Log FC	0.13*** (4.19)	0.03 (0.86)	0.04 (1.04)	-0.01
Δ Lag FPI	-0.08* (-2.28)	-0.05* (-2.28)	-0.05* (-2.33)	0.00
R^2	0.23	0.23	0.25	-
F-statistic (Prob > F)	10.33*** (0.00)	3.53** (0.01)	-	-
F test that all u_i=0:	-	37.34*** (0.00)	-	-
Wald chi2(3) (Prob > chi2)	-	-	11.31** (0.01)	-
LM (Prob > chibar2)	-	-	356.17*** (0.00)	-
Hausman: chi2(3) (Prob>chi2)	-	-	-	0.46 (0.93)

Notes. (i) t and z-statistics are reported in parentheses; (ii) ***, **, and * represent statistical significance at the 1 %, 5 %, and 10 % level, respectively.

Source: panel models' results.

Although the result of the POLS shows a positive significant effect of the fertilizer consumption on the food import (food stability), the results of the FE and RE expose not statistically significant for the coefficient of fertilizers consumption (Table 9). This might be related to the orientation of agricultural policy of GCC countries towards increasing and depending on the domestic fertilizer consumption specifically the organic fertilizers. Also because of the desert topography and unfertile lands of the Gulf region, the consumption of fertilizers is high.

In contrast, the F-statistic, $p < 0.05$, then the FE model is more recommended than the POLS. However, the Breusch-Pagan LM test indicates that the POLS method became preferable around the random-effects model, $p < 0.05$. In opposition, the Hausman test accepted the null hypothesis, therefore the Hausman test indicates that the variables were correlated and reveals that the RE method became preferable to the FE model ($p > 0.05$). Like the model of the food availability, based on the results of the F-statistic, Breusch-Pagan LM and Hausman, the RE was chosen as most appropriate for the food stability model (Table 9).

Moreover, as shown in Table 10, the results point out that of all estimated models a negative correlation is observed when analyzing fertilizers consumption with the prevalence of obesity (food utilization). This might be related to other factors affecting the prevalence of obesity, for instance, several scholars argue that the dependency on processed imported food leads to an increase in the prevalence of obesity [67; 68]. The population coefficient resulting from the EF model shows a statically significant positive effect on food utilization (prevalence of obesity).

Table 10

Challenges of food utilization in the GCC countries (2000–2020)

Model	Estimators			
	POLS (CCM) (t-value)	FE (LSDV) (t-value)	RE (GLS) (Z-value)	Difference (FE-RE)
Constant	1.53*** (22.82)	1.14*** (8.70)	1.45*** (18.13)	-
Δ log POPU	0.00 (0.56)	0.11** (3.53)	0.02 (1.24)	0.12
Log FC	-0.05*** (-3.60)	-0.04* (-3.32)	-0.03* (-2.83)	-0.03
Δ Lag FPI	0.03 (1.76)	0.02 (1.27)	0.02 (1.33)	0.00
R^2	0.03	0.15	0.31	-
F-statistic (Prob > F)	6.65*** (0.00)	5.86*** (0.00)	-	-
F test that all u_i=0:	-	9.15*** (0.00)	-	-
Wald chi2(3) (Prob > chi2)	-	-	12.78*** (0.00)	-
LM (Prob > chibar2)	-	-	34.23*** (0.00)	-
Hausman: chi2(3) (Prob>chi2)	-	-	-	11.18** (0.01)

Notes. (i) t and z-statistics are reported in parentheses; (ii) ***, **, and * represent statistical significance at the 1 %, 5 %, and 10 % level, respectively.

Source: panel models' results.

The food price inflation (FPI) shows no significant effect on food utilization (prevalence of obesity), when we compare our result of the FPI with the study performed by Matz et al. [69], they examine the impacts of rising food prices on food security indicators, indicate that food price inflation has impacted the reductions in the number and frequency of meals consumed, but has little impact on diet diversity indicators, or on calorie consumption. Similar Wang [42] confirms that food price did not influence food security.

Furthermore, from Table 10 we concluded that the FE model was an adequate option (in comparison to POLS, F-test result (0.00). In contrast, the Breusch-Pagan LM test rejects the null hypothesis, and this shows that the pooled method became preferable over the random-effects model, and this indicates that there are suggestions of significant differences in food utilization across GCC countries, at the same time, the Hausman test rejected the null hypothesis such as the Breusch-Pagan LM test, which indicates that the variables were uncorrelated ($p < 0.05$). Referring to these tests the FE model is an appropriate option for analyzing the food utilization model.

Brief view of the obtained results for the different models and specifications, it appears that the social factor (total population) is an important challenge of food security [70]. The results for other challenges are mixed and differ between the panel models. And lastly, the combination of these challenges has impacted food security in the GCC countries.

Conclusions. Boosting food security represents a key priority for policymakers in oil GCC countries, hence the GCC countries established the strategies and visions for ensuring food security to meet the population growth for the coming decades. The current study aims to identify the most challenges of food security across the GCC countries and tries to investigate the most appropriate model of the econometric approach for achieving the goal of this study.

Using three alternatives of panel data analysis, POLs, FE, and RE, the present study attempts to identify the challenges of food security across GCC countries for the period (2000–2019). The study focuses on the three substantial challenges that impact the food security indicators: social (total population), economic (food price inflation), and agri-environmental (fertilizers consumption) challenges. The food production, gross domestic product per capita, food import, and prevalence of obesity variables are selected to represent the food availability, access, stability, and utilization; respectively.

The findings of PPMC and VIF results expose that food production, has a negatively correlated with GDP, food import, population, and fertilizers consumption, and appositively correlated with obesity and food price inflation. In the same manner GDP, and food imports negatively correlated with obesity and positively correlated with population. Furthermore, obesity and population have signed a negative relationship between fertilizers consumption. Fertilizer consumption has a statistically significant association with all variables except food price inflation. The outcomes also confirm that there is no multicollinearity between the explanatory variables.

The preliminary analysis pointed out that, a cross-sectional dependence exists within variables for VOFI, POB, POPU, and FC. Likewise, our findings show no existence of a cross-sectional dependence between AFP and GDP variables.

The results confirm that population growth is a significant driver of food security indicators in the GCC countries, in particular, the food stability indicators. Moreover, food price inflation has a significant impact on the food production (food availability) and food imports (food stability). The food price inflation shows no significant effect on food access and food utilization. Fertilizer consumption has significant challenges the food utilization. Considering results obtained from the food access model the results of the Breusch-Pagan test suggest that the FE method became preferable to the pooled and random-effects model and conclude that there is proof of significant differences in food security among the GCC countries.

Concerning the appropriate model of the panel models analysis, the study concludes that random effects estimators of regression coefficients of food availability and stability challenges are more statistically efficient than those for POLS and fixed effects. While the fixed effects estimators are most preferred for the coefficients of food access and utilization challenges.

The study recommends that decision-makers initiate interventions that promote food security via increasing food imports and channeling foreign direct investment in agricultural products to meet the continual increase in population. However, our research is restricted to the three challenges and hence the results cannot be generalized to all food security challenges. To overcome this limitation, future research should be conducted on other factors affecting food security.

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References

1. FAO (2021). *The State of Food and Agriculture 2021. Making agrifood systems more resilient to shocks and stresses*. FAO, Rome. https://doi.org/10.4060/cb4476en.

2. FAO (2019). How to feed the world in 2050. FAO, Rome. Available at: http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf.

3. Bhuyan, B., Sahoo, B. K., & Suar, D. (2020). Food insecurity dynamics in India: A synthetic panel approach. *Social Sciences & Humanities Open*, 2(1), 100029. https://doi.org/10.1016/j.ssaho.2020.100029.

4. Poudel, D., & Gopinath, M. (2021). Exploring the disparity in global food security indicators. *Global Food Security*, 29(2021), 100549. https://doi.org/10.1016/j.gfs.2021.100549.

5. Mohammadi, E., Singh, S. J., McCordic, C., & Pittman, J. (2022). Food security challenges and options in the Caribbean: insights from a scoping review. *Anthropocene Science*, 1(1), 91–108. https://doi.org/10.1007/s44177-021-00008-8.

6. Abulibdeh, A., Zaidan, E., & Al-Saidi, M. (2019). Development drivers of the water-energy-food nexus in the Gulf Cooperation Council region. *Development in Practice*, 29(5), 582–593. https://doi.org/10.1080/09614524.2019.1602109.

7. KSA Vision (2016). Saudi Vision 2030. Saudi Arabia: the government of Saudi Arabia. Available at: https://www.vision2030.gov.sa/v2030/overview.

8. Ministry of Cabinet Affairs and the Future (2020). Future Possibilities Report 2020. Abu Dhabi, Government of United Arab Emirates. Available at: https://digitallibrary.un.org/record/3898825.

9. Alharthi, M. (2019). Determinants of economic development: a case of Gulf Cooperation Council (GCC) Countries. *International Journal of Economics and Finance*, 11(11), 12–18. https://doi.org/10.5539/ijef.v11n11p12.

10. World Bank (2020). International migrant stock (% of the population). Available at: https://data.worldbank.org/indicator/SM.POP.TOTL.ZS.

11. Lin, H. I., Yu, Y. Y., Wen, F. I., & Liu, P. T. (2022). Status of food security

in East and Southeast Asia and challenges of climate change. *Climate*, 10(3), 40. https://doi.org/10.3390/cli10030040.

12. FAOSTAT (2021). Statistical data. Available at: https://www.fao.org/statistics.

13. The Economist Intelligence Unit (2020). Global Food Security Index 2020: building resilience in the face of rising food-security risks. Available at: https://foodsecurityindex.eiu.com.

14. Hassen, T. B., & El Bilali, H. (2019). Food security in the Gulf Cooperation Council Countries: challenges and prospects. *Journal of Food Security*, 7(5), 159–169. https://doi.org/10.12691/jfs-7-5-2.

15. Devesh, S., & Affendi, A. M. A. (2020). Food security dynamics in Oman: VECM approach. *Advances in Dynamical Systems and Applications*, 15(2), 249–263. https://doi.org/10.37622/ADSA/15.2.2020.249-263.

16. Lampietti, J. A., Michaels, S., Magnan, N., McCalla, A. F., Saade, M., & Khouri, N. (2011). A strategic framework for improving food security in Arab countries. *Food Security*, 3(1), 7–22. https:/doi.org/10.1007/s12571-010-0102-3.

17. Pirani, S. I., & Arafat, H. A. (2016). Interplay of food security, agriculture, and tourism within GCC countries. *Global food security*, 9, 1–9. https://doi.org/10.1016/j.gfs.2016.05.002.

18. Al-Saidi, M., & Saliba, S. (2019). Water, energy and food supply security in the Gulf Cooperation Council (GCC) countries – a risk perspective. *Water*, 11(3), 455. https://doi.org/10.3390/w11030455.

19. Al-Handhali, K. Y., & Miniaoui, H. (2020). Food security in the GCC Countries: towards a more diversified and sustainable economic development. In H. Miniaoui (Eds.), *Economic development in the Gulf Cooperation Council Countries* (pp. 75–88). Gulf Studies, vol. 1. Springer, Singapore. https://doi.org/10.1007/978-981-15-6058-3_4.

20. FAO (2014). The state of food insecurity in the world 2014. FAO, Rome. Available at: https://www.fao.org/3/i4030e/i4030e.pdf.

21. Ghose, B. (2014). Food security and food self-sufficiency in China: from past to 2050. *Food and Energy Security*, 3(2), 86–95. https://doi.org/10.1002/fes3.48.

22. Hall, C., Dawson, T. P., Macdiarmid, J. I., Matthews, R. B., & Smith, P. (2017). The impact of population growth and climate change on food security in Africa: looking ahead to 2050. *International Journal of Agricultural Sustainability*, 15(2), 124–135. https://doi.org/10.1080/14735903.2017.1293929.

23. Tscharntke, T., Clough, Y., Wanger, T. C., Jackson, L., Motzke, I., Perfecto, I., Vandermeer, J., & Whitbread, A. (2012). Global food security, biodiversity conservation, and the future of agricultural intensification. *Biological conservation*, 151(1), 53–59. https://doi.org/10.1016/j.biocon.2012.01.068.

24. Abegaz, K. H. (2017). Determinants of food security: evidence from Ethiopian Rural Household Survey (ERHS) using pooled cross-sectional study. *Agriculture and Food Security*, 6(1), 70. https://doi.org/10.1186/s40066-017-0153-1.

25. Kassy, W. C., Ndu, A. C., Okeke, C. C., & Aniwada, E. C. (2021). Food

security status and factors affecting household food security in Enugu State, Nigeria. *Journal of Health Care for the Poor and Underserved*, 32(1), 565–581. https://doi.org/10.1353/hpu.2021.0041.

26. Badghan, F., Namdar, R., & Valizadeh, N. (2020). Challenges and opportunities of transgenic agricultural products in Iran: convergence of perspectives using Delphi technique. *Agriculture and Food Security*, 9, 4. https://doi.org/10.1186/s40066-020-00259-5.

27. He, G., Geng, C., Zhao, Y., Wang, J., Jiang, S., Zhu, Y., Wang, Q …. & Mu, X. (2021). Food habit and climate change impacts on agricultural water security during the peak population period in China. *Agricultural Water Management*, 258, 107211. https://doi.org/10.1016/j.agwat.2021.107211.

28. Faisal, I. M., & Parveen, S. (2004). Food security in the face of climate change, population growth, and resource constraints: implications for Bangladesh. *Environmental Management*, 34(4), 487–498. https://doi.org/10.1007/s00267-003-3066-7.

29. Premanandh, J. (2011). Factors affecting food security and contribution of modern technologies in food sustainability. *Journal of the Science of Food and Agriculture*, 91(15), 2707–2714. https://doi-org.sdl.idm.oclc.org/10.1002/jsfa.4666.

30. Molotoks, A., Smith, P., & Dawson, T. P. (2021). Impacts of land use, population, and climate change on global food security. *Food and Energy Security*, 10(1), e261. https://doi.org/10.1002/fes3.261.

31. Blekking, J., Waldman, K., Tuholske, C., & Evans, T. (2020). Formal/informal employment and urban food security in Sub-Saharan Africa. *Applied Geography*, 114, 102131. https://doi.org/10.1016/j.apgeog.2019.102131.

32. Ridoutt, B., Baird, D., Bastiaans, K., Hendrie, G., Riley, M., Sanguansri, P., Syrette, J., & Noakes, M. (2016). Changes in food intake in Australia: comparing the 1995 and 2011 National Nutrition Survey results disaggregated into basic foods. *Foods*, 5(2), 40. https://doi.org/10.3390/foods5020040.

33. Bahadur, KC. K., Legwegoh, A. F., Therien, A., Fraser, E. D. G., & Antwi-Agyei, P. (2018). Food price, food security, and dietary diversity: a comparative study of urban Cameroon and Ghana. *Journal of International Development*, 30(1), 42–60. https://doi.org/10.1002/jid.3291.

34. Webb, P., Danaei, G., Masters, W. A., Rosettie, K. L., Leech, A. A., Cohen, J., Blakstad, M. … & Mozaffarian, D. (2021). Modelling the potential cost-effectiveness of food-based programs to reduce malnutrition. *Global Food Security*, 29, 100550. https://doi.org/10.1016/j.gfs.2021.100550.

35. Salahodjaev, R., & Mirziyoyeva, Z. (2021). The link between food security and life satisfaction: panel data analysis. *Sustainability*, 13(5), 2918. https://doi.org/10.3390/su13052918.

36. Gödecke, T., Stein, A. J., & Qaim, M. (2018). Global burden of chronic and hidden hunger: trends and determinants. *Global food security*, 17, 21–29. https://doi.org/10.1016/j.gfs.2018.03.004.

37. Ubaid-ur-Rehman, H., Asghar, W., & Khalid, N. (2021). Food security

challenges for Pakistan during COVID-19 pandemic: an overview of the response plan. *World Food Policy*, 7(1), 82–89. https://doi.org/10.1002/wfp2.12026.

38. Viana, C. M., Freire, D., Abrantes, P., Rocha, J., & Pereira, P. (2022). Agricultural land systems importance for supporting food security and sustainable development goals: a systematic review. *Science of The Total Environment*, 806(3), 150718. https://doi.org/10.1016/j.scitotenv.2021.150718.

39. Zhang, J., Tian, H., Shi, H., Zhang, J., Wang, X., Pan, S., & Yang, J. (2020). Increased greenhouse gas emissions intensity of major croplands in China: Implications for food security and climate change mitigation. *Global Change Biology*, 26(11), 6116–6133. https://doi.org/10.1111/gcb.15290.

40. Yadav, S. S., Hegde, V., Habibi, A. B., Dia, M., & Verma, S. (2019). Climate change, agriculture, and food security. In S. S. Yadav, R. J. Redden, J. L. Hatfield, A. W. Ebert, D. Hunter (Eds.), *Food Security and Climate Change*. https://doi.org/10.1002/9781119180661.ch1.

41. Demeke, A. B., Keil, A., & Zeller, M. (2011). Using panel data to estimate the effect of rainfall shocks on smallholder's food security and vulnerability in rural Ethiopia. *Climatic Change*, 108, 185–206. https:// doi.org/10.1007/s10584-010-9994-3.

42. Wang, J. (2010). Food security, food prices and climate change in China: a dynamic panel data analysis. *Agriculture and Agricultural Science Procedia*, 1, 321–324. https://doi.org/10.1016/j.aaspro.2010.09.040.

43. Xin, Y., & Tao, F. (2021). Have the agricultural production systems in the North China Plain changed towards to climate-smart agriculture since 2000? *Journal of Cleaner Production*, 299, 126940. https://doi.org/10.1016/j.jclepro.2021.126940.

44. Chandio, A. A., Gokmenoglu, K. K., Ahmad, M., & Jiang, Y. (2021). Towards sustainable rice production in Asia: the role of climatic factors. *Earth Systems and Environment*, 6(1), 1–14. https://doi.org/10.1007/s41748-021-00210-z.

45. Alnaser, W., & Alnaser, N. (2011). The status of renewable energy in the GCC countries. *Renewable and sustainable energy reviews*, 15(6), 3074–3098. https://doi.org/10.1016/j.rser.2011.03.021.

46. GCC-STAT (2012). Population Statistics in GCC Countries 2016–2019. Available at: https://gccstat.org/en/statistic/publications/population-statistics-in-gcc-countries.

47. World Bank (2021). *World Development Indicators, Data Bank*. Available at: https://databank.worldbank.org/source/world-development-indicators.

48. Breusch, T. S., & Pagan, A. R. (1980). The Lagrange multiplier test and its applications to model specification in econometrics. *The Review of Economic Studies*, 47(1), 239–253. https://doi.org/10.2307/2297111.

49. Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica*, 46(6), 1251–1271. https://doi.org/10.2307/1913827.

50. Salisu, A. A., & Isah, K. O. (2017). Revisiting the oil price and stock market nexus: a nonlinear panel ARDL approach. *Economic Modelling*, 66, 258–271. https://doi.org/10.1016/j.econmod.2017.07.010.

51. Jarque, C. M., & Bera, A. K. (1980). Efficient tests for normality, homoscedasticity, and serial independence of regression residuals. *Economics Letters*, 6(3), 255–259. https://doi.org/10.1016/0165-1765(80)90024-5.

52. Pesaran, M. H., Ullah, A., & Yamagata, T. (2008). A bias-adjusted LM test of error cross-section independence. *The Econometrics Journal*, 11(1), 105–127. https://doi.org/10.1111/j.1368-423X.2007.00227.x.

53. Levin, A., Lin, C. F., & Chu, C. (2002). Unit root tests in panel data: asymptotic and finite-sample properties. *Journal of Econometrics*, 108(1), 1–24. https://doi.org/10.1016/S0304-4076(01)00098-7.

54. Dickey, D. A., & Fuller, W. A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, 49(4),1057–1072. https://doi.org/10.2307/1912517.

55. Breitung, J., & Das, S. (2005). Panel unit root tests under cross-sectional dependence. *Statistica Neerlandica*, 59(4), 414–433. https://doi.org/10.1111/j.1467-9574.2005.00299.x.

56. Hernández-Salmerón, M., & Romero-Ávila, D. (2015). Econometric Methods. In *Convergence in output and its sources among industrialised countries*. *A cross-country time-series perspective* (pp. 15–24). Cham, Springer. https://doi.org/10.1007/978-3-319-13635-6_3.

57. Werkmann, V. (2013). Performance of unit root tests in unbalanced panels: experimental evidence. *AStA Advances in Statistical Analysis*, 97(3), 271–285. https://doi.org/10.1007/s10182-012-0203-8.

58. Baltagi, B. H. (2001). *Econometric analysis of panel data*, 4th ed. Wiley, John, and Sons.

59. Park, H. M. (2011). *Practical guides to panel data modeling: a step-by-step analysis using stata*. Public Management and Policy Analysis Program. International University of Japan. Available at: https://www.iuj.ac.jp/faculty/kucc625/method/panel/panel_iuj.pdf.

60. Greene, W. H. (2003). *Econometric analysis*, 5th ed. New York University. Available at: https://spu.fem.uniag.sk/cvicenia/ksov/obtulovic/Mana%C5%BE.%20%C5%A1tatistika%20a%20ekonometria/EconometricsGREENE.pdf.

61. Sun, P., Wu, B., Li, X., Li, W., Duan, L., & Gan, C. (2021). Counterfactual debiasing inference for compositional action recognition. In *Proceedings of the 29th ACM International Conference on Multimedia* (pp. 3220–3228). https://doi.org/10.1145/3474085.3475472.

62. Pickson, R. B., & Boateng, E. (2022). Climate change: a friend or foe to food security in Africa? *Environment, Development and Sustainability*, 24, 4387–4412. https://doi.org/10.1007/s10668-021-01621-8.

63. Amolegbe, K. B., Upton, J., Bageant, E., & Blom, S. (2021). Food price volatility and household food security: evidence from Nigeria. *Food Policy*, 102, 102061. https://doi.org/10.1016/j.foodpol.2021.102061.

64. Boulanger, P., Dudu, H., Ferrari, E., Mainar-Causapé, A. J., & Ramos, M. P.

(2022). Effectiveness of fertilizer policy reforms to enhance food security in Kenya: a macro-micro simulation analysis. *Applied Economics*, 54(8), 841–861. https://doi.org/10.1080/00036846.2020.1808180.

65. Xiang, T., Malik, T. H., & Nielsen, K. (2020). The impact of population pressure on global fertilizer use intensity, 1970–2011: an analysis of policy-induced mediation. *Technological Forecasting and Social Change*, 152, 119895 https://doi.org/10.1016/j.techfore.2019.119895.

66. Wardhani, F. S., & Haryanto, T. (2020). Foreign direct investment in agriculture and food security in developing countries. *Contemporary Economics*, 14(4), 510–521. https://doi.org/10.5709/ce.1897-9254.422.

67. Adams, J., & White, M. (2015). Characterisation of UK diets according to degree of food processing and associations with socio-demographics and obesity: cross-sectional analysis of UK National Diet and Nutrition Survey (2008–2012). *International Journal of Behavioral Nutrition and Physical Activity*, 12(1), 160. https://doi.org/10.1186/s12966-015-0317-y.

68. Poti, J. M., Braga, B., & Qin, B. (2017). Ultra-processed food intake and obesity: what really matters for health-processing or nutrient content? *Current obesity reports*, 6(4), 420–431. https://doi.org/10.1007/s13679-017-0285-4.

69. Matz, J. A., Kalkuhl, M., & Abegaz, G. A. (2015). The short-term impact of price shocks on food security-evidence from urban and rural Ethiopia. *Food Security*, 7(3), 657–679. https://doi.org/10.1007/s12571-015-0467-4.

70. Barretto, R., Buenavista, R. M., Rivera, J. L., Wang, S., Prasad, P. V., & Siliveru, K. (2021). Teff (Eragrostis tef) processing, utilization and future opportunities: a review. *International Journal of Food Science & Technology*, 56(7), 3125–3137. https://doi.org/10.1111/ijfs.14872.

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