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Identifying Determinants of Food Security Using Panel Data Analysis: Evidence from Maghreb Countries

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Abstract: Countries and international bodies are focusing on agriculture as a route to achieving sustainable food security. Hence, the aim of this study is to examine the determinants of food security. It investigates the effects of gross domestic product deflator (GDPD), rural population, arable area, agricultural workers, farmers, agricultural exports, and agricultural imports on agricultural performance, which is a metric of food security. This study uses time lapse data models of a sample from the group of Maghreb states, namely Libya, Tunisia, Algeria, Morocco, and Mauritania, for the 2003–2018 period. All these data were collected from the statistical reports of the Arab Organization for Agricultural Development. The results provide evidence of the significant positive impacts of gross domestic product, arable areas, and agricultural exports on the agricultural sector's performance, which results in achieving food security. However, the results indicate that the rural population and the number of workers in the agricultural sector have a significantly negative relationship with agricultural sector performance. In terms of agricultural imports, the results do not show a relationship between agricultural imports and agricultural sector performance. To the best of the researchers' knowledge, this is the first study conducted in the Maghreb states, including five countries. This study alerts policymakers to issues regarding the importance of having effective policies that could enhance the performance of agricultural production to achieve food security in the Maghreb states. Policymakers must improve the investment climate in North African countries to encourage investors to enter the agricultural sector.

Keywords: agricultural performance; food security; gross domestic product; arable area; panel data; Maghreb

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1. Introduction

Food security is a complex topic that is frequently seen from the perspective of available resources, with a focus on accessibility and availability (O'Connell et al. 2023). Food insecurity is still a significant issue in many countries (Dagdeviren et al. 2023). Despite advancements in the international agenda to eliminate food insecurity over recent decades, it has remained a global concern (Weldemariam et al. 2023). Hence, achieving the goal of food security is one of the strategic goals for countries in general, Maghreb countries, and international regional organizations. The latter are now not looking to achieve the concept of food security in its narrow sense; rather, they are looking to achieve the concept of sustainable food security and its goal of building a world without hunger by the year 2030.

The United Nations Sustainable Development Goals (SDGs) comprise 17 goals which aim to eradicate all forms of hunger, to achieve SDG 2 of Zero Hunger, and eliminate malnutrition by the year 2030 as one of their main objectives (Dagdeviren et al. 2023); globally, a significant proportion of communities are struggling to cope with hunger (Weldemariam et al. 2023). Despite efforts made by countries and regional bodies to eradicate hunger, this goal remains out of reach according to the latest report by the Food and Agriculture Organization of the United Nations (FAO) for the year 2021; the latest statistics showed that the level of hunger in the world increased in 2020 in light of the outbreak of the COVID-19 pandemic, and after the prevalence of food shortage remained largely unchanged for five years, rising from 8.4% to about 9.9% in just one year (World Health Organization 2019).

There are certainly other elements that can be viewed as dimensions contributing to food security (Clapp et al. 2022). This makes it more difficult to meet the goal of the total eradication of hunger by 2030. If the 2018 statistics are taken as an example, the number of people suffering from hunger rose in this period. The number of people suffering from hunger reached 820 million, with African countries having the highest rate, estimated to be 19.9%. The countries of West Asia also witnessed a continuous rise in the rate of hunger since 2010, reaching 11.3%, in addition to Latin American countries that have known a significant rate, which was estimated at 6.5% (World Health Organization 2019).

These unforeseen consequences can be explained by the economic, social, and political upheavals witnessed in several regions of the world in general and the Arab world in particular in the past decade, where the unstable political situations in Syria, Libya, and Yemen have affected the stability of food security in these countries. In addition, the global health crisis of 2020 caused by the COVID-19 pandemic and the absence of any effective medicine or vaccine has led to a deterioration in the economic and social situations of several countries, which has adversely affected their food security (Arndt et al. 2020).

This global health crisis has provided major motivation to state leaders to seriously consider the concept of self-sufficiency with regard to their food resources. The impact of this health crisis on the global transport system has negatively impacted the supply of these countries. Therefore, the achievement of very high levels of self-sufficiency in food resources has become one of the main factors in achieving food security. Over the past 50 years, the definition of food security has been altered and expanded, including the addition of the four often-referenced pillars of food security: availability, access, usage, and stability (Clapp et al. 2022).

Further, the availability of financial resources for the importation of agricultural products is not enough to achieve food security, especially in times of crisis, and the agricultural productive capacities of states should be increased to achieve food independence. Importantly, agriculture continues to be the foundation of many African economies, despite moves towards industrialization and the increased exploitation of natural resources, such as oil and minerals (Balgah et al. 2023).

The Maghreb countries are located on the continent with the highest rate of malnutrition in the world, as well as the political crises witnessed by some countries in recent years, such as Tunisia, Egypt, and Libya, which inevitably affected the levels of import capacity in these countries. In addition, the oil crisis of 2014 negatively affected the financial resources of some countries, such as Algeria and Libya, and all these changes in cumulation have negatively affected the supply of food and nutrition policies in these countries.

In the literature on food security, the dimension of food security has received little attention (Weldemariam et al. 2023). Further, there is still a gap in the knowledge related to characterizing the most important determinants of food security in the Maghreb countries, and this topic needs more investigation. Determining the extent to which African countries have attempted to achieve SDG 2, Zero Hunger, regarding food security is critical to the current study of food security in Maghreb countries. Hence, the aim of this study is to examine the determinants of food security. It investigates the effects of gross domestic product, rural population, arable area, agricultural workers, farmers, agricultural exports,

and imports on agricultural performance; this is a metric of food security in the group of Maghreb states, namely Libya, Tunisia, Algeria, Morocco, and Mauritania.

The motivation for selecting the Maghreb states is that a food security crisis has erupted in North Africa. Food inflation levels in Tunisia, Algeria, and Morocco are at levels not seen since a decade ago. The primary weakness of the Maghreb is its heavy reliance on imported cereal grains for both human and animal nutrition. In September 2021, the average price of grains climbed globally by 27.3% in comparison to September of the previous year, and prices have subsequently risen even more quickly (Tanchum 2021). Designing local and national governance structures is urgently needed due to the extensive use of natural resources in the Maghreb, particularly by the agricultural sector. In the absence of explicit policies, there are growing disparities between farmers who can afford to keep making further investments to ensure they have enough resources and others who must modify their crop production to account for the scarcity (Faysse et al. 2011).

Focusing on food production capacities is important. If these have been subject to shock and crises, concerns will arise about food insecurity (Chiwona-Karltun et al. 2021). Agricultural resources have drastically decreased, while regional conflicts and harsh weather events have added to the difficulties (Bai et al. 2023). Indeed, agriculture is the backbone of developing economies (Okeke et al. 2023), especially for many African economies (Chiwona-Karltun et al. 2021), since it provides food and, as a result, raises people's standard of living. Consequently, increasing food production is an urgent requirement in meeting the needs of this population that is constantly growing (Okeke et al. 2023).

Therefore, the current study will make a big contribution to the existing literature on food security by adding new evidence to examine the determinants of food security, specifically the effect of gross domestic product, rural population, arable area, workers in the agriculture, agricultural exports, and imports on agricultural performance.

The study will assist governments and policymakers worldwide and in Maghreb countries to determine the factors that affect agricultural production, which is a primary contributor to food security success. The study will provide some recommendations for policymakers that could be made in terms of gross domestic product, arable area, and agricultural/food exports: promoting desert farming, encouraging banks to grant loans to farmers, providing tax incentives to the agricultural sector, promoting trade in agricultural products, and encouraging inter-Maghreb agriculture.

The following section of the paper reviews the previous literature related to food security, including a definition of food security, food security characteristics, and the self-sufficiency ratios of the Arab Maghreb States. Section 3 illustrates the research methodology, and Section 4 presents the results of the study. A robustness test is presented in Section 5. Further, Section 6 provides a discussion of the results. Lastly, Section 7 provides a conclusion to the paper.

2. Literature Review and Statistical Reports

The concept of food security represents a new expression that was created with the goal of eradicating hunger, which affects mainly developing countries. The number of people suffering from the problem of nutrition has been reported to be about one billion. The proportion of people suffering from malnutrition started to decline, reaching 820 million people in 2018, or about 11% globally. This number returned to an increase with the global health crisis after 2019 because of the COVID-19 pandemic that affected the entire globe. The latter resulted in the disruption of transport between countries, which led to the weakness of supply for countries that have not achieved good levels of self-sufficiency for food.

International bodies such as the Food and Agriculture Organization of the Arab League for Agricultural Development and Food Security aimed to achieve the concept of sustainable food security and the definitive eradication of the phenomenon of hunger in the world within the year 2030, but after the COVID-19 pandemic, this goal became difficult to achieve. According to Alinovi et al. (2010), Africa's population accounts for

almost 25% of the world's hungry people, and Sub-Saharan Africa ranks second to South Asia on the Global Hunger Index. The following sections highlight the most important aspects of food security.

2.1. Definition of Food Security

Several definitions of food security have been formulated. The 1996 World Food Summit developed a comprehensive definition of food security that is being used to this day: "Food security is achieved when all human beings at all times have access, both physically and economically, to adequate, safe, and nutritious food that meets their nutritional needs and suits their dietary tastes to lead an active and healthy life (Horizon 2017)".

Article 03 of Act No. 08-16 of 3 August 2008, Agricultural Directive, defines the Algerian law as "easy and regular access for everyone to a healthy and sufficient food that allows them to enjoy an active life (Official Gazette of the Algerian Republic 2008)". Food security was further defined as "the capacity of society to provide for the basic nutritional needs of the people and to ensure a minimum of those basic nutritional needs, either (i) produce locally or (ii) produce part of it and meet other needs by providing an adequate yield of agricultural exports used to import these needs (Salam 1998)".

Through the above definitions, the concept of food security is based on three elements: (i) ensure adequate and reliable nutritional supply for all families; (ii) ensure relative stability from year to year in the level of supplies; and (iii) ensure that every family has the material, social, and economic means for proper nutrition. Indeed, food security does not mean the extent to which families are provided with food. Rather, food security has become a broader concept, which is the extent to which food is provided to all families in a healthy and permanent manner.

Two levels of food security, absolute food security and relative food security, can be distinguished: Absolute food security means producing food within the state equal to or above domestic demand, a level that is intended to be fully self-sufficient. Relative food security means the ability of a state or a group of states to provide the necessary foodstuffs to cover its domestic demand in full, whether through domestic production, cooperation with other states, or what is known as export and import (Oreibi 2013).

The human element is considered to be an important factor in the development of the agricultural sector in any country; about 80% of the exploiters of agricultural land in both Asia and Africa are small farmers and family investors. This makes them one of the most important producers in the agricultural sector in the countries of the two continents (Swiss Agency for Development and Cooperation 2015). This makes the number of workers in the agricultural sector an important indicator of the extent to which the self-sufficiency of the agricultural sector is achieved in any country.

2.2. Food Security Characteristics

According to FAO (2008), food security is based on four basic dimensions that can be summarized by the following points:

Food supply: Concerned with the volume of food supply, determined by three variables: the volume of domestic food production, stock level, and net trade.

Physical access to food: Good levels of food stocks at the national and international levels do not guarantee the food security of families. The important problem is due to income, expenditure, and price policies. The fact that there is an abundance of food supplies on the market does not necessarily mean food security if families cannot obtain the food they need because of poor purchasing power or a difficult supply.

Good food use: The concept of good food use is meant to provide the necessary food, not necessarily through proper nutrition. The way the body can benefit from the food should be found through proper nutrition methods, the way food is prepared, and the diet used within the family through diversification into healthy foods that allow for the provision of body calories to avoid vitamin deficiency or obesity.

Previous 3D stability over time: A stabilization variable is extremely important, even if real-time nutrition is healthy. Researchers cannot predict the future; an unstable nutrition situation might occur through the vagaries of various ambient environmental factors (drought, flood, earthquake, etc.), or political instability or economic disruptions (like unemployment, rising prices), all of which will negatively affect stability and the level of food security. The various dimensions of food security are illustrated in Figure 1.

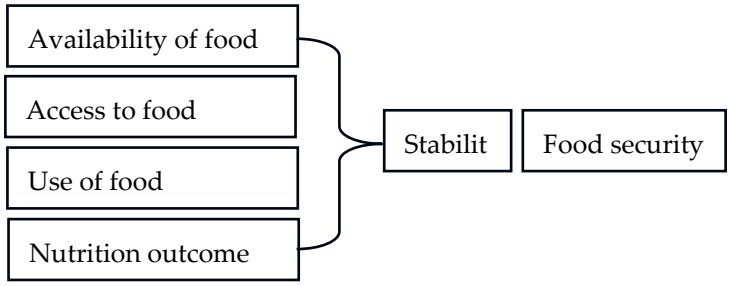

Figure 1. Food security dimensions. Source: (Sirhan and Abdulameer 2017).

Figure 1 shows that the concept of food security has not become limited to either providing food to families or simply obtaining food. Rather, there are very important variables: stability and sustainability. Therefore, most of the recent trends in the concept of food security speak of the sustainability of food security.

2.3. Self-Sufficiency Ratios of the Arab Maghreb States for the Period 2016–2018

Through this point, the authors analyze the levels of self-sufficiency in four of the most important divisions, namely the grain division, the vegetable division, the fruit division and, finally, the meat division, during the period 2016–2018 for all the countries studied. This is accomplished through the following points.

2.3.1. Grain Division

The most important data on agricultural production, exports, imports, and consumption of the division of grain for all Maghreb countries can be summarized from the statistics provided by the Arab Organization for Agricultural Development, presented in Table 1.

Table 1. Self-sufficiency ratios for Maghreb countries (grain division).

Countries	Production (10^3 Tonnes)		Exports (10^6 USD)		Imports (10^6 USD)		Trade Balance (10^6 USD)		Consumption (10^3 Tonnes)		Self-Sufficiency (%)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Tunisia	1677.95	1424.12	2.48	10.15	759.45	829.43	756.97	819.28	5267.37	4953.03	31.86	28.75
Algeria	3478.07	6065.94	0.11	0.04	2746.32	2860.37	2746.21	2860.33	16,370.28	22,799.31	21.25	26.61
Libya	178.92	219.55	13.55	0.84	1009.29	665.57	995.74	664.74	2526.64	3357.65	7.08	6.54
Morocco	9787.16	10,387.39	0.49	7.31	3314.63	1557.84	3314.14	1550.53	14,248.06	17,015.23	68.69	61.05
Mauritania	357.30	435.10	-	-	136.08	211.47	136.08	211.47	976.41	1293.00	36.59	33.65

Source: Yearbook of Arab Agricultural Statistics, Arab Organization for Agricultural Development, No. 39, Part 9, Commodity Balances for Food Groups, Table No. 593, 2019 (Excel file).

Table 1 shows that all Maghreb countries were not fully self-sufficient in 2017 and 2018. The same applied in the statistics for the years prior to this period. This result was not expected because of the natural resources available to these countries. For example, Algeria has great potential in Saharan agriculture, which meets all the conditions that allow for the development of this division but has not been exploited in a good way until recently, when the state encouraged Saharan farming. It has been noticed that the level of self-sufficiency in the division of grain did not exceed 30% during the two years, meaning that the Algerian production of cereals did not cover one-third of the consumer demand.

The authors further notice the weakness of the value of exports, which did not exceed USD 1 million; in contrast, the value of imports was considered and estimated at more than USD 2.5 billion during the two years. This is due to the great demand for this substance resulting from the consumption pattern characteristic of the Arab countries. On the contrary, the authors note that the self-sufficiency ratio was acceptable in Morocco, where it was nearly 70% in 2017, despite the great demand for these materials, estimated this year to be about USD 14 billion.

Production was estimated to be at about USD 9 billion, and the difference was provided through imports. Both Tunisia and Mauritania achieved close proportions of about 30%, but there is a difference in values, as Mauritania is characterized by weak production and weak demand. In contrast, Tunisia was in demand for about USD 5 billion, and production was about USD 2 billion. The weakest percentage was in Libya, where this percentage did not exceed 10%. This is due to the large demand for these materials and the weak production, estimated at USD 200 million.

2.3.2. Vegetables Division

The most important data on the self-sustainment ratios of the vegetables division are summarized in Table 2.

Table 2. Self-sufficiency ratios for Maghreb countries (vegetables division).

Countries	Production (10^3 Tonnes)		Exports (10^6 USD)		Imports (10^6 USD)		Trade Balance (10^6 USD)		Consumption (10^3 Tonnes)		Self-Sufficiency (%)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Tunisia	3695.53	3457.47	33.75	66.54	10.51	9.96	−23.24	−56.58	3672.38	3416.86	100.63	101.19
Algeria	8882.46	17,351.22	4.19	12.31	20.81	46.18	16.62	33.87	8884.26	17,380.87	99.98	99.83
Libya	921.72	927.33	0.29	5.66	6.39	32.81	6.09	27.15	923.43	955.95	99.82	97.01
Morocco	5016.75	5607.23	813.52	1471.50	11.85	56.55	−801.68	−1414.95	4363.70	4374.48	114.97	128.18
Mauritania	7.21	8.83	0.02	14.57	38.44	40.93	38.41	26.37	14.80	106.44	48.68	8.29

Source: Yearbook of Arab Agricultural Statistics, Arab Organization for Agricultural Development, No. 39, Part 9, Commodity Balances for Food Groups, Table 602, 2019.

From the data in Table 2, most of the countries studied achieved good rates of self-sufficiency in the vegetable division; this percentage was close to 100% for Libya, Algeria, and Tunisia, which explains the weak value of imports for these countries. As for Morocco, this percentage exceeded 100%; that is, it achieved full self-sufficiency in this division, and the surplus was directed to exports, as the value of exports exceeded the value of imports in this division.

It may be noted that states should develop the food industries in the divisions where the surplus was achieved so that they can direct this surplus for export. For example, in Algeria, some divisions, such as tomatoes and potatoes, achieved a large surplus in production that exceeded national demand. Because of the absence of a manufacturing industry and the lack of storage capacity, part of the surplus was damaged. The state that achieved the exception in the Maghreb region of this division is Mauritania, where the percentage of self-sufficiency did not exceed very different proportions.

2.3.3. Fruit Division

Based on the data shown in Table 3, the self-sustainment ratios achieved in the Maghreb countries can be analyzed in the fruit division during 2017 and 2018.

From the data shown in Table 3, three countries achieved full self-sufficiency: Algeria, Morocco, and Tunisia. Here, the self-sufficiency ratio exceeded 100% for the countries in 2018. This ratio was approached in 2017 for Algeria and was higher for Tunisia and Morocco, which explains the increase in the value of exports compared to imports. Libya achieved acceptable ratios in the two years, which were estimated at about 90%.

Table 3. Self-sufficiency ratios for the Arab Maghreb countries (fruit division).

Countries	Production (10^3 Tonnes)		Exports (10^6 USD)		Imports (10^6 USD)		Trade Balance (10^6 USD)		Consumption (10^3 Tonnes)		Self-Sufficiency (%)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Tunisia	1481.61	1405.65	195.74	327.16	18.02	37.52	−177.72	−289.64	1411.51	1284.70	104.97	109.41
Algeria	4942.65	4779.84	38.85	111.19	96.12	72.16	57.27	−39.03	4978.28	4770.13	99.28	100.20
Libya	395.30	394.22	1.23	5.79	12.01	38.83	10.77	33.05	411.16	445.24	96.14	88.54
Morocco	4850.95	4667.30	581.51	1013.20	78.59	271.08	−502.92	−742.12	4289.76	4034.91	113.08	115.67
Mauritania	25.49	25.29	-	-	4.95	8.81	4.95	8.81	37.27	44.52	68.39	56.82

Source: Yearbook of Arab Agricultural Statistics, Arab Organization for Agricultural Development, No. 39, Part 9, Commodity Balances for Food Groups, Table 603, 2019.

The value of imports in the countries that achieved more than 100% self-sufficiency can be explained by the fact that production in the division exceeded demand, but there are some fruits that should be imported because they cannot be produced locally, like some tropical fruits, but the best import income comes from the financing of exports to the same division. It is also noted that Mauritania has achieved a reasonable percentage in this division, estimated at about 60%, although the country's figures show weak production and weak demand (which raises the question of the credibility of the statistics provided for this country).

2.3.4. Meat Division

According to the data shown in Table 4, the self-sufficiency ratios of the Maghreb countries for meat division can be explained and analysed during 2017 and 2018.

Table 4. Self-sufficiency ratios for the Arab Maghreb countries for the meat division.

Countries	Production (10^3 Tonnes)		Exports (10^6 USD)		Imports (10^6 USD)		Trade Balance (10^6 USD)		Consumption (10^3 Tonnes)		Self-Sufficiency (%)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Tunisia	341.27	319.30	8.21	2.62	10.98	23.75	2.77	21.13	336.74	324.20	101.35	98.49
Algeria	1073.70	1069.00	0.37	0.43	188.84	187.04	188.46	186.61	1123.30	1120.56	95.58	95.40
Libya	181.63	180.47	-	-	109.59	182.75	109.59	182.75	245.27	296.88	74.05	60.79
Morocco	1268.54	1289.58	1.27	1.34	30.07	40.14	28.81	38.80	1274.49	1297.73	99.53	99.37
Mauritania	113.04	112.47	0.90	-	19.08	20.39	18.17	20.39	135.60	138.04	83.36	81.48

Source: Yearbook of Arab Agricultural Statistics, Arab Organization for Agricultural Development, No. 39, Part 9, Commodity Balances for Food Groups, Table 609, 2019.

Based on Table 4, it can be stated that all countries achieved similar proportions in terms of self-sufficiency in the meat division, where the ratios ranged between 90% and 99% in Tunisia, Algeria, and Morocco. The highest percentages were in Morocco and Tunisia, where they were close to 100% (full self-sufficiency). However, despite the good ratios, which were close to 100%, the possibilities of all the Arab Maghreb countries allow them to take the lead in this division and achieve high rates of exports, as authors have noticed that the value of exports in this division did not exceed USD 8 million, which is very weak. Unlike the aforementioned three countries, Libya and Mauritania achieved an acceptable ratio of 70% in the first and 80% in the second. But they can cover this deficit in the future as they have weak demand compared to neighboring countries.

After analyzing the self-sustainment ratios during the years 2017 and 2018, the authors summarize the self-sufficiency ratios for the four divisions during the 2016–2018 tripartite period in Table 5.

Table 5. Self-sufficiency ratios of the Maghreb countries for the different divisions during the period 2017–2018.

Statement	Country	Tunisia	Algeria	Libya	Morocco	Mauritania
Grain division self-sustainment ratio	2016	26.2	20.5	7.4	27.7	41.5
	2017	31.9	21.2	7.1	68.7	36.6
	2018	28.8	26.6	6.5	61.0	33.7
Vegetables division self-sustainment ratio	2016	101.5	99.4	96.5	124.0	13.7
	2017	100.6	100.0	99.8	115.0	48.7
	2018	101.2	99.8	97.0	128.2	8.3
Fruit division self-sustainment ratio	2016	108.2	95.2	91.4	139.6	57.5
	2017	105.0	99.3	96.1	113.1	68.4
	2018	109.4	100.2	88.5	115.7	56.8
Meat division self-sufficiency ratio	2016	100.8	94.1	71.5	99.3	82.8
	2017	101.3	95.6	74.1	99.5	83.4
	2018	98.5	95.4	60.8	99.4	81.5

Source: Yearbook of Arab Agricultural Statistics, Arab Organization for Agricultural Development, No. 39, Part 9, Commodity Balances for Food Groups, Tables Nos. 593, 602, 603 and 609, 2019.

Table 5 shows that some of the countries in the sample achieved good levels of self-sufficiency, such as the divisions of vegetables, fruits, and meat, especially in the countries of Tunisia, Algeria, and Morocco. Libya and Mauritania were exceptions, and the only area that did not achieve self-sufficiency for all the countries in the sample during the period was the division of cereals, with a low rate that did not exceed 30%. This was the case despite the material and human resources that are available in these countries, except for Morocco, where this percentage exceeded 60% in 2017 and 2018. Therefore, the Maghreb countries should invest more in these divisions more, so that they can achieve dependability in this division. The authors also noted a fluctuation in the statistics related to the Mauritanian state during the studied period, where production and consumption levels were weak.

After analyzing the self-sufficiency ratios of the countries in the sample study, considering the self-sufficiency variable to be one of the basic variables in achieving the concept of food security, the authors carry out a standard study to determine the determinants affecting the variables that measure the productivity of the agricultural sector in the Maghreb countries. This is seen as an indicator of the variability of food security for these countries. This is achieved through a study using a panel data analysis for Maghrib Countries during the period of time between 2003 and 2018. The following hypotheses are suggested:

H_1. *There is a significant relationship between the GDPD value and production performance.*

H_2. *There is a significant relationship between rural population and production performance.*

H_3. *There is a significant relationship between the arable area and production performance.*

H_4. *There is a significant relationship between workers in the agriculture sector and production performance.*

H_5. *There is a significant relationship between agriculture exports and production performance.*

H_6. *There is a significant relationship between agriculture imports and production performance.*

3. Methodology

The study contains a sample of all the countries of the Arab Maghreb, i.e., Libya, Tunisia, Algeria, Morocco, and Mauritania, during the period 2003–2018. The data were collected from the statistical reports of the Arab Organization for Agricultural Development (the Annual Book of Statistics, from 25 to 39). Accordingly, the study used the panel model using the economic data of the Maghreb countries (5 countries) during the period 2003–2018. The Arab Maghreb countries were selected for their economic, geographical, and cultural

similarities. Regarding the statistical model, this study will use the panel model because the data used have two dimensions: the dimension for each segment, the study units (countries in the sample), five countries, and the period dimension, which is 16-year study periods.

The statistical data published in the statistical reports of the Arab Organization for Agricultural Development have been relied upon to avoid inconsistencies in the statistics when using different sources of information. Based on these reports, a database containing statistical indicators for the Maghreb countries was established during the period studied (population, rural population, total labor, number of workers in the agricultural sector, GDPD, output from the agricultural sector, state area, planted area, total exports, agricultural exports, food exports, total imports, agricultural imports, and food imports).

Based on this information, as well as on previous studies on this subject, e.g., Sirhan and Abdulameer (2017) and Pawlak and Kołodziejczak (2020), several variables that can be relied upon to interpret the determinants of the productivity of the agricultural sector as an indicator of the food security of these countries have been selected. These variables are defined in Table 6. First, gross domestic production is a financial indicator that quantifies a nation's economic production per person. This variable was included as there was a significant relationship between population and agricultural productivity. Second, rural population refers to the population living in rural areas where people are often more focused on agriculture production.

Table 6. Measurement of variables.

Variable Name	Variable Symbol	Calculation Method	Previous Studies
		Dependent variable	
Agricultural Productivity	RSA	$RSA = \log\left(\frac{\text{GDP(Agriculture sector)}}{\text{Population number}}\right)$	(Mahrous 2019)
		Independent Variables	
Per Capita Product Variable	GDPD	GDPD = log (GDP deflator)	(Hitzhusen and Jeanty 2006; Salahodjaev and Mirziyoyeva 2021)
Rural Population Variable	PR	PR = log (rural population)	-
Arable Area	AL	AL = log (Planted area)	(Hitzhusen and Jeanty 2006; Ndjadi et al. 2019; Singh 2018; Sun and Zhang 2021)
Number of Workers in the Agricultural Sector	EA	EA = log (Agriculture workers)	(Fusco et al. 2020; Hitzhusen and Jeanty 2006; Sun and Zhang 2021)
Agricultural Exports	EAL	EAL = Food exports/Total exports	(Asche et al. 2015)
Food Exports	EAG	EAG = Agricultural exports/Total exports	(Asche et al. 2015)
Agricultural Imports	IAG	IAG = Agricultural imports/Total Imports	(Asche et al. 2015)
Food Imports	IAL	IAL = Food imports/Total Imports	(Asche et al. 2015)

Third, arable area refers to land capable of being plowed and used to grow crops, where increasing the arable area will increase agricultural productivity. Fourth, the number of workers in the agricultural sector refers to agricultural workers, who are the critical elements of agricultural production, where high numbers of workers could increase agricultural production. It found that the annual labor productivity increased as a result of the increase in the employment of workers (Smirnova and Postnova 2020).

Fifth, agricultural exports and food exports refers to the percentage of agricultural and food exports, where there is a positive relationship between agriculture production efficiency and the percentage of agricultural and food exports. Sixth, agricultural imports and food imports refer to the proportion of agricultural and food imports when the relationship between agriculture production efficiency and the percentage of agricultural and food imports is negative.

Based on the variables shown in Table 6, the model to be assessed can be formulated through the following two equations:

$$RSA_{it} = \alpha + \beta_1 GDPD_{it} + \beta_2 PR_{it} + \beta_3 AL_{it} + \beta_4 EA_{it} + \beta_5 EAG_{it} + \beta_6 IAG_{it} + (\mu_i + \nu_{it}). \quad \text{(Model 1)}$$

$$RSA_{it} = \alpha + \beta_1 GDPD_{it} + \beta_2 PR_{it} + \beta_3 AL_{it} + \beta_4 EA_{it} + \beta_5 EAL_{it} + \beta_6 IAL_{it} + (\mu_i + \nu_{it}) \quad \text{(Model 2)}$$

where

$$i = 1, \ldots, 5 \ \& \ t = 1, \ldots, 16.$$

The first model will use the export and import variables for agricultural products, while the second model will use the import and export variables for foodstuffs.

4. Results

The study aims to investigate the impact of the above-mentioned independent variables on the productivity rate of the agricultural sector, which serves as a food security indicator in the studied sample. The multiple regression method was employed to analyze the data from the Arab Maghreb countries. As a first step, the Fischer test was used to find the appropriate model, studying whether the model of integrated data (equals constant) or the model of individual effects should be used.

After entering the sample statistical data in STATA 11, the data format was defined as a first step (5 divisions uniting 16 years of study). Then, to instruct the process of estimating the effects of the Fisher's test result (Asteriou and Hall 2007), the results of the Fisher test are shown in Table 7.

Table 7. Fisher test results.

Ficher Test		
Number of obs = 80	Fixed-effects (within) regression	
Number of groups = 5	Group variable: enterprise	
Prob > F = 0.0000	F(4.69) = 37.32	F test that all ui = 0

From the Fischer test, it is noted that it is less likely that the null hypothesis of 5% is rejected, and from that, the alternative hypothesis that the individual effects model is the best for estimation is accepted.

Based on the results obtained from these two models, before the authors analyzed the results obtained from an economic perspective, the authors sought to determine whether there is a linear relationship between the different independent variables. In terms of the multicollinearity test, the study relied on two indicators to measure the existence of a multiple linear relationship between the separate variables of the model. The first indicator is the variance inflation factor (VIF). The second indicator is the degree of tolerance (Tolérance). If the variance inflation factor of an independent variant is greater than 10 and the corresponding tolerance is less than 0.1 (1/VIF), in this case, it can be concluded that this variable is only a linear relationship of other independent variables. The VIF values of the tolerances of the two models are summarized in Table 8.

Table 8. The variation inflation factor and the tolerance index indicate the model variables.

Variables	**Model 1**		**Variables**	**Model 2**	
	VIF	**1/VIF**		**VIF**	**1/VIF**
GDPD	1.04	0.963023	GDPD	1.06	0.942021
PR	2.94	0.340000	PR	2.84	0.352257
AL	1.40	0.711886	AL	1.68	0.594741
EA	2.59	0.385874	EA	2.75	0.363748
EAG	1.99	0.501651	EAL	2.22	0.451044
IAG	1.17	0.854056	IAL	1.33	0.752554
Average VIF	1.86		Average VIF	1.98	

Model 1 uses the export and import variables for agricultural products while model 2 uses the import and export variables for foodstuffs.

On the basis of Table 8, it can be stated that all the VIF values were less than 3, while the tolerance values were all greater than 0.34, which indicates the absence of collinearity between the independent variables.

Regarding the Hausman test, it was confirmed by the previous test that the best model for estimation is the special effects model. The Hausmann test allows for a distinction between the "estimation within" fixed-effects model and the "GLS" random-effects model, by comparing the parameters of the two models (Goaied and Sassi 2012). Table 9 shows the results of the Hausmann test.

Table 9. Housman test results.

Hausman Fixed Random				
Variables	**Coefficients**			
	(b) Fixed	**(B) Random**	**(b-B) Difference**	**sqrt(diag(V_b-V_B)) S.E**
GDPD	0.2933995	0.5214118	−0.2280122	-
PR	−2.131068	0.2154535	−2.346522	0.118535
AL	1.602603	0.2963694	1.306234	0.4465488
EA	−0.2219904	−0.1058309	−0.1161595	-
EAG	0.147692	0.2374444	−0.0897524	-
IAG	−0.2080376	−0.1415965	−0.066441	-
Test: Ho: difference in coefficients not systematic chi2(6) = (b-B)′[(V_b-V_B)^(-1)](b-B) =101.88 Prob > chi2 = 0.0000				

From the results, it can be stated that the probability value of any square equal to 0 is less than the morale level of 5%. So, it is preferred to use the fixed-effects model in the estimation process.

After determining the model to be used in this field study, namely the linear regression model under the panel data using the fixed-effects model, the results are shown in Table 10.

Table 10. The parameters of the two models.

Variables	**Model 1**	**Variables**	**Model 2**
Constant (C)	−2.9209 * (1.631)	Constant (C)	−2.6535 (1.595)
(GDPD)	0.2933 *** (0.099)	(GDPD)	0.2777 *** (0.096)
Rural Population (PR)	−2.1310 *** (0.292)	Rural Population (PR)	−2.1080 *** (0.290)
Arable Area (AL)	1.6026 *** (0.448)	Arable Area (AL)	1.5307 *** (0.438)
Number of workers in the agriculture sector (EA)	−0.2219 (0.142)	Number of workers in the agriculture sector (EA)	−0.2495 * (0.141)
Agriculture exports (EAG)	0.1476 (0.095)	Food exports (EAL)	0.3981 ** (0.169)
Agriculture imports (IAG)	−0.2080 (0.164)	Food imports (IAL)	−0.2841 (0.232)
Number of Observation used	80	Number of Observation used	80
Number of CUs per year	5	Number of CUs per year	5
Facture of Rho	0.9907	Facture of Rho	0.9900
F(6.69)	24.54	F(6.69)	25.69
Prob > F	(0.0000)	Prob > F	(0.0000)

Model 1 uses the export and import variables for agricultural products while model 2 uses the import and export variables for foodstuffs; *, **, and *** indicate significance at levels of 0.10, 0.05, and 0.01, respectively. Robust standard errors in parentheses, Definitions of variables are given in Table 6.

Based on Table 10, it can be stated that the number of observations used in the model was estimated at 80 (16 × 5). Also, the Fischer F(6; 69) statistics show that the model has a good morale of 24.54 and 25.69, respectively, with an estimated probability of a significant level at 1%. The latter is below the morale level of 1%, meaning that the model has a high degree of statistical significance, whereas the Rho factor is above 99% in the two models, meaning that about 99% of the changes are the result of the variation across units of the panel data.

From the table, it can be observed that the gross domestic product deflator (GDPD), the rural population (PR), the arable area (AL), and the food exports (EAL) had the highest level of significant effect at 1% and 5% in the two models; no statistical significance was found for the import variable, whether agricultural or food, in the two models.

For further explanation, the results show that there is a significant positive relationship between gross domestic product and agricultural sector performance, which results in achieving food security. The result confirms the hypothesis where the authors expected a positive relationship between gross domestic product and agricultural sector performance. This means that a high gross domestic product increases agricultural productivity.

In terms of the rural population, it significantly negatively affects the agricultural sector's performance. This means that a large rural population results in decreasing agricultural production, which is an unexpected result and is in opposition to the hypothesis that expected positive results. Regarding arable area, the results show a significant positive relationship, as proposed by the study hypothesis. The result indicates that the increase in the arable area resulted in increased agricultural sector performance, leading to achieving food security.

Concerning the effect of the number of workers in the agricultural sector on agricultural sector performance, the results show an insignificant relationship in model 1 and a significant negative relationship in model 2, in opposition to the hypothesis where the authors expected that a high number of workers could increase agricultural production. In terms of agricultural and food exports, the results show a significant positive effect on the agricultural sector performance in model 2, which led to achieving food security, as the study expected. This means that increasing agricultural production efficiency results in increasing agricultural exports. Regarding agriculture and food imports, these were not found to have a relationship with agricultural sector performance.

5. Robustness Test

Initially, the study used a fixed-effects panel model in its static form to consider the influence of country characteristics. However, due to the problem of endogeneity and the inability to determine causal relationships between variables (Arellano and Bond 1991) and the problem of some omitted variables, another method of estimation was resorted to through a dynamic panel based on System GMM to give more robustness to the estimation and to tackle the problem of endogeneity and the problem of eliminating differences between countries.

The factors affecting agricultural productivity are dynamic and depend strongly on previous observations, so System GMM provides more consistent results. This method also addresses the bias of the coefficients arising from estimation using a static panel. Therefore, the fixed-effects model was re-estimated by performing a System GMM estimator. The System GMM results are presented in Table 11.

Based on the System GMM findings, the effect of GDPD per capita and AL are positive and significant in both models, in contrast to the negative effect of the PR on agricultural productivity in the Maghreb countries. In general, these results represent the same estimation outcomes using the fixed-effects method. It is also noted that the estimation using the System GMM showed the same results as presented in Table 10, which indicates that the findings are robust.

Table 11. System GMM estimation results.

Variables	Model 1	Variables	Model 2
RSA(L1)	0.9024 *** (0.1168)	RSA (L1)	0.8926 *** (0.1183)
(GDPD)	0.2209 ** (0.1136)	(GDPD)	0.2039 * (0.1183)
Rural Population (PR)	−0.7769 ** (0.3165)	Rural Population (PR)	−0.8412 *** (0.3201)
Arable Area (AL)	1.0400 *** (0.3575)	Arable Area (AL)	1.0723 *** (0.3592)
Number of workers in the agriculture sector (EA)	−0.0799 (0.1079)	Number of workers in the agriculture sector (EA)	−0.1264 (0.1071)
Agriculture exports (EAG)	0.1476 ** (0.1076)	Food exports (EAL)	0.3189 * (0.1992)
Agriculture imports (IAG)	−0.0714 (0.1669)	Food imports (IAL)	−0.0405 (0.2102)
Constant (C)	−2.5113 (1.269) *	Constant (C)	−2.5279 * (1.295)
AR(1) *p*-value	0.3871	AR(1) *p*-value	0.4133
AR(2) *p*-value	0.2862	AR(2) *p*-value	0.4969
Sargan test (*p*-value)	174.15 (1.00)	Sargan test (*p*-value)	204.702 (1.00)

*, **, and *** indicate significance at levels of 0.10, 0.05, and 0.01, respectively. Robust standard errors in parentheses. Time and country dummy variables used to control the fixed effect (see Appendix A).

6. Discussion

Based on the results shown in Table 10 and confirmed by Table 11, the relationship between the independent variables and the dependent variables can be explained as follows:

Variable measuring GDPD: Results show a strong correlation between this variable and the agricultural sector performance variable, which is the same result as that presented in several studies (Salahodjaev and Mirziyoyeva 2021; Sun and Zhang 2021). This can be explained by the fact that good economic growth in any country has a positive impact on all sectors. As the agricultural sector is a strategic sector for the Maghreb, the rising value of GDPD allows the state to strengthen its investment capacities in the agricultural sector to achieve food security.

Rural population: From this finding, it can be stated that there is an inverse relationship between this variable and the change in the performance of the agricultural sector, which is an unexpected result. This result can be explained by the fact that, despite the rate of urbanization in societies, the authors have noticed several countries that have witnessed development in their agricultural sectors, where it is not necessary for a peasant to be from the countryside. It is necessary to look to the large agricultural investments that are not linked to the number of workers or to their place of residence, but which rely mainly on technological developments in the field.

Planting area variable: The results show a strong correlation between this variable and the performance of the agricultural sector. This is the same result that was reached in several studies, including, but not limited to, the study of (Hitzhusen and Jeanty 2006; Singh 2018). This can be explained by the fact that the increase in the proportion of planted areas allows for the strengthening of the productive capacities of states. Therefore, countries like Algeria should turn to desert farming through land reclamation, as past experiences have shown the profitability of desert farming; Algeria is one of the countries with small, cultivated areas compared to the total area of the state.

Number of workers in the agricultural sector: From the results, it can be observed that there was an inverse relationship between this variable and the agricultural sector performance variable in the second model; this variable had no statistical significance in the first model, which is an unexpected result (Sun and Zhang 2021). Other studies have not found any statistical significance for this variable, such as the results of the first model (Hitzhusen and Jeanty 2006).

This result can be explained by the fact that modern agricultural techniques have become a strategic alternative to the human element. The human factor has not remained the main factor in the development of the agricultural sector. Rather, technology should be used to increase its capabilities, which corresponds to the results obtained with regard to the rural population, where large agricultural investments that are not linked to the number of workers or their place of residence should be directed to the agricultural field, relying mainly on scientific development.

Export variable: In both models, it can be stated that there is a correlation between the variable of exports of agricultural materials or foodstuffs and that of the performance of the agricultural sector. This can be explained by the fact that the dynamics of exports in the agricultural sector encourages the Maghreb countries to strengthen their productive capacities.

Import variable: An inverse relationship in both models between the import variable and the agricultural sector performance variable was observed, but this result cannot be relied upon in the analysis because it has no statistical significance.

7. Conclusions

The goal of achieving food security has become a preoccupation for countries and regional bodies, with the aim of combating and eradicating hunger within the year 2030. However, the COVID-19 pandemic has made this goal difficult to achieve. After several years of stability in the number of people suffering from undernutrition, this number has increased in the latest statistics in the wake of the COVID-19 pandemic. Therefore, the goal of achieving sustainable food security requires greater efforts because of epidemics, tensions between states, and the emergence of several hotbeds of conflict, which negatively affect the poverty rates in the world.

In these circumstances, the countries of the Maghreb have tried to achieve good rates of self-sufficiency in the most important peasant divisions. Through this research, it can be stated that most Maghreb countries have achieved good rates of self-sufficiency in terms of the vegetable, fruit, and meat divisions during the period 2016–2018. The only division that showed weak production in comparison with consumer demand for all countries is the grain division. Therefore, the governments of the Maghreb countries should find the necessary solutions to achieve balance in this division, so that it does not find itself in an unstable situation, especially in times of crisis.

The results show that there is a significant positive relationship between gross domestic product and agricultural sector performance, which results in achieving food security. In terms of the rural population, it significantly negatively affects the agricultural sector's performance. Regarding arable area, the results show a significant positive relationship, where increasing arable area resulted in increased agricultural sector performance, leading to achieving food security. Concerning the effect of the number of workers in the agricultural sector on agricultural sector performance, the results show an insignificant relationship in model 1 and a significant negative relationship in model 2. In terms of agricultural and food exports, the results show a significant positive effect on agricultural sector performance, leading to achieving food security. Regarding the agricultural and food imports, they do not have a relationship with agricultural sector performance.

The present study provides some recommendations for policymakers that could be made in terms of gross domestic product, arable area, and agricultural/food exports. The study found a significant positive association between those variables and agricultural sector performance. First, policymakers should promote the use of desert farming in agriculture. Second, policymakers should encourage banks to grant loans to farmers so that they can invest in agriculture.

Third, policymakers should provide tax incentives to the agricultural sector to increase output and promote the convenience of conducting business. The tax incentive is a component of the government's modernization of the agricultural sector, which aims to increase its productivity for the requirements of the country and ensure its independence. Fourth, policymakers should improve the investment climate in North African countries

to encourage investors to enter the sector. Lastly, policymakers should promote trade in agricultural products and encourage intra-Maghreb agriculture. These recommendations will maintain and strengthen the positive relationships found in the study.

In terms of the variables of the rural population and the number of workers in the agriculture sector, the present study suggests the following actions that could be taken by policymakers. The results of these variables were significantly negatively associated with agricultural sector performance, instead of having a positive relationship. First, young people should be encouraged to invest in agriculture and not leave this activity to the rural population only. Second, training in the field of agriculture should be developed, particularly in vocational training centers and institutes. Policymakers must give full support to the rural population, which will attract them to efficiently engage in agriculture, and increase their performance to be more productive, thus enhancing food security.

The current study has some limitations because it contains data only from Maghreb states (Libya, Tunisia, Algeria, Morocco, and Mauritania) for the period 2003–2018. Further, it may not contain all the variables that may affect food security. Hence, future studies may focus on a wide range of countries and include more variables that may affect food security.

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Appendix A

The estimation after adding a dummy variable for each year and for each country.

Appendix A.1. First Model

Table A1. Time dummy variables.

Year	Coeff	SE
2004	0.0275377	0.1072826
2005	0.0001169	0.1102068
2006	0.0524994	0.1174722
2007	0.1134095	0.1201748
2008	0.2152741 *	0.1275046
2009	0.2326708 *	0.1203718
2010	0.2027449	0.1333331
2011	0.1437	0.1430693
2012	0.1445395	0.1483038
2013	0.1725536	0.1512333
2014	0.2397714	0.1499107
2015	0.2542021 *	0.1460983
2016	0.2357291	0.1534674
2017	0.208337	0.1556565
2018	0.2399688	0.16236

*, **, and *** indicate significance at levels of 0.10, 0.05, and 0.01, respectively.

Table A2. Country dummy variable.

Country	Coeff	SE
2	−0.2376458 **	0.1105217
3	−0.2166682	0.1698479
4	−0.2325553	0.1419086
5	1.933824 ***	0.5154368

*, **, and *** indicate significance at levels of 0.10, 0.05, and 0.01, respectively.

Appendix A.2. Second Model

Table A3. Time dummy variables.

Year	Coeff	SE
2004	0.0237329	0.1023533
2005	−0.0076575	0.1082949
2006	0.0593187	0.1127646
2007	0.1260735	0.1144196
2008	0.2309624 **	0.123427
2009	0.2341503 **	0.1162404
2010	0.2128017 *	0.1265858
2011	0.1405051	0.1384387
2012	0.1586919	0.1425332
2013	0.1887546	0.1447365
2014	0.2563816 *	0.1428684
2015	0.2836747 **	0.1395698
2016	0.272921 *	0.1455727
2017	0.2278945	0.1469239
2018	0.2675325 *	0.1535163

*, **, and *** indicate significance at levels of 0.10, 0.05, and 0.01, respectively.

Table A4. Country dummy variable.

Country	Coeff	SE
2	−0.2091205 *	0.1101707
3	−0.2187669	0.1677313
4	−0.227495	0.1387687
5	1.837741 ***	0.5049931

*, **, and *** indicate significance at levels of 0.10, 0.05, and 0.01, respectively.

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