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**AN ANALYSIS OF THE  
ECONOMIC DETERMINANTS OF  
FOOD SECURITY IN NORTH  
AFRICA**

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## **AN ANALYSIS OF THE ECONOMIC DETERMINANTS OF FOOD SECURITY IN NORTH AFRICA<sup>3</sup>**

This paper investigates the issue of food security as the basis for stable economic development using the example of North Africa. A statistical analysis of economic and financial factors in relation to the determinants of food security was carried out using a panel cointegrating model based on official international statistics of the Food and Agriculture Organization (FAO) and the World Bank for 1991-2014. According to the results, population growth and the intensification of agricultural production, foreign trade and foreign direct investment play a crucial role in food security. The study revealed the relationship between food security and the development of the banking and financial systems in the region, and their degree of globalization. The strategy of a long-term investment policy pursued by the World Bank and FAO to combat hunger and poverty was justified. The methodology proposed can be used to monitor and evaluate the effectiveness of policies to maintain food security in the regions of Africa.

JEL Classification: C22, C53, F52, I38, R11.

Keywords: food security, financial institutions, financial markets, panel cointegration, time series analysis, economic indicators, statistical data, North Africa

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# 1 Introduction

One of the important goals of humanity is the sustainable development of society<sup>4</sup>. This is difficult to imagine without progress in the eradication of hunger and malnutrition. Despite the fact that enough food is produced in the world to feed everyone, the Food and Agriculture Organization (FAO) estimates about 792.5 million people in 2015 continued to suffer from chronic hunger<sup>5</sup>. The number of undernourished people and the prevalence of undernourishment in Africa in 2014-2016 was 230.3 million people and 19.8%, respectively. During the period from 1990-1992 to 2014-2016 there was a decrease in the prevalence of undernourishment (by 23.4%), but the number of undernourished people doubled.

Several international organizations under aegis of FAO completed an agreement to ensure food security<sup>6</sup> in developing countries. The aim is to reduce hunger in the world by half by 2025. All such programs long implementation horizons. One of the necessary measures is the annual investment in the development of rural areas of on average US\$265 billion. Such investment flows require the constant monitoring of the situation and the evaluation of possible risks and the effectiveness of the policy, based on a thorough consideration of general long-term indicators for food security and socio-economic development.

This work analyses and identifies the long-term links between different economic factors and food security, to determine general trends, using the example of the North African countries and the World Bank and FAO data 1991-2014. Compared to other African regions, in this region the results of the analysis of food security are the most optimistic, since they show the effectiveness of existing measures and necessity to study the region's positive experience. This paper proposes a methodology of econometric modelling based on a panel cointegration of time series identified in FAO official statistics. The proposed research technique allows an analysis of the long-term dynamics of economic factors and food security, a comparison of the short-term and long-term effects, a study of reactions to shocks and periods of reaction attenuation. The results indicate that population growth and the development of agricultural production, foreign trade and foreign direct investment (FDI) play a crucial role in the problem of food security. During the period 1991-2014 general trends of food security and the level of development of banking financial institutions in the region, their degree of globalization were revealed.

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<sup>4</sup> FAO and the 17 Sustainable Development Goals, 2015. Available at: <http://www.fao.org/3/a-i4997e.pdf>

<sup>5</sup> FAOstat. Available at: <http://faostat3.fao.org/download/I/IC/E>

<sup>6</sup> **Food security** exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life. (FAO) Available at: <http://www.fao.org/economic/ess/ess-fs/en/>

The structure of the paper is as follows. Section 2 provides a literature review. Section 3 contains the main research hypotheses. Section 4 describes the data, descriptive statistics and methodology used in the study. Section 5 presents the test and regression analysis results. The paper ends with a discussion and conclusions in the sixth section.

## **2 Literature review**

### **2.1. Factors of Food Security**

The key factors in the formation of food security are not obvious. The stabilization of food security is possible in different ways, which are determined by the socio-economic situation in the country. In the literature on food security different concepts to explain the determinants of food security are stressed (Craig, Scanlan, 2001): modernization, economic dependency, urban bias, neo-Malthusian population pressure, ecological evolutionary processes, militarism and others.

In *modernization theory* internal sources of economic development play an important role. Domestic investment and the development of education are a reliable basis for industrialization and the cultural transformation of society, which leads to economic growth and the creation of stronger institutions, contributing to improve the overall welfare of the population. Strong political institutions, and the democratization of society contributes to economic and social development, inhibits corruption, encourages the growth of public investment in nutrition, education and health, provides political stability, improves the quality of life, all of which significantly affects food security (Safaei, 2006). Some authors (Inkeles, Smith, 1974; Barro, 1991) suggest that investment in human capital, raising the education level, improves the quality of the labour force. An educated labour force is also an important component of economic growth. Economic development, industrialization, education, and urbanization can improve the quality of life, and economic growth has a positive effect on the food supply, infant survival, and adult longevity in general. According to modernization theory, the inflow of foreign capital and technology contribute to economic growth, increase the incomes of all groups of people, and as a result, reduce the risk of hunger in the country and increase the potential of food security (Shen, Williamson 1997; Firebaugh, Beck 1994; Scanlan, 2004).

In *economic dependency theory* international trade and foreign investment have a negative impact on social security. Studies have shown that export dependence reduces economic growth and the quality of life, the total food supply, and contributes to child mortality (Wickrama, 1996). Foreign investment has a negative effect on food security for several reasons. Multinational

corporations repatriate most of their profits and prevent the formation of domestic firms, which leads to a reduction of domestic economic growth. Foreign investment is largely focused on advanced technology and the creation of a smaller number of jobs, although highly paid, which contributes to the inequality of income, and poverty. Foreign investment is mainly concentrated in exporting industries and has weak links with the internal market, which also has a negative impact on domestic production. In the short-term foreign investment flows can create economic growth, but the long-term effects of the penetration of foreign capital is negative (Mihalache-O'keef, Quan, 2011).

In *urban bias theory* the political power of urban elites is a key element. It directs resources to the cities, which leads to an imbalance in the income of urban and rural populations, slows economic growth, and reduces the quality of life (Breedlove, Armer, 1997). All these phenomena degrade food security conditions.

According to *neo-Malthusian population pressure*, rapid population growth leads to environmental “extremes” in terms of over-cultivation, the use of excess fertilizers, deforestation, land degradation which may ultimately undermine food security (Urdal, 2005). However, neo-Malthusian population pressure concerns rapid population growth in countries with low food security. In general, the growth of the country's population can be accompanied by positive trends in food security indicators. So the necessity to provide the population with food requires the development of agricultural production and technology, and the creation of additional employment. It can promote economic growth and improve the situation with food. Ghana is an example in which there was an increase in the population in 1990-2016 from 15 to 27 million people. At the same time, the growth of the population of the country was accompanied by the development of agriculture, economic growth and the improvement of the situation with food security<sup>7</sup>.

In *ecological-evolutionary theories* the traditional way of ploughing agricultural land, and its high density contributed to rapid industrialization and improved the welfare of the population (Crenshaw, Ameen, 1993). The development of agriculture is an important component of food security.

In the concept of *militarism* military conflicts, political repression, and international arms races led to a decrease of public investment in the basic needs of the population (nutrition, health, education), reducing the aggregate food supply. All this increases the risks of food security and child hunger (Austin, McKinney, 2012).

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<sup>7</sup> The State of Food Insecurity in the World 2015(FAO). P.29. Available at: <http://www.fao.org/3/a-i4646e.pdf>

These concepts of food security are reflected in the research related to Africa. To solve the problems of food security in Africa FAO experts have identified some important factors: economic growth, increased agricultural productivity, the development of international trade, social protection and a strengthening of the financial system<sup>8</sup>. Agriculture in Africa has a key role in the economy and is a significant proportion of GDP, employment and trade. Skoet (2004), Christiaensen, Demery, Kuhl (2011) show that the growth of agricultural production in Africa is more effective in reducing extreme poverty compared to the growth in non-agricultural sectors. Asuming-Brempong (2003) illustrate with the example of Ghana that the institutional reforms and the investments carried out in the framework of the Medium-Term Agricultural Development Program in 1991-2000 stimulated the growth of domestic food production. Wahlley (2012) reveals the positive contribution of Chinese foreign direct investments (FDI) in the period of 1990-2008 to GDP growth in African countries. Investigations of the FDI effect in these countries (Alfaro, Chanda, Kalemli-Ozcan, Sayek, 2004; Durham, 2004) indicate that only countries with well-developed financial markets significantly benefit from FDI in terms of their growth rates and there is the risk of excessive economic dependence on FDI. FAO 2015<sup>9</sup> reports the positive and negative effects of trade liberalization on the economic security of the country. It shows that the impact of trade liberalization on the eradication of poverty and hunger is ambiguous and that the role of globalization of the financial system is increasing. Existing concepts allow us to propose a series of assumptions regarding the factors influencing food security in the countries of North Africa, which is discussed further in the hypothesis section, and tested in the present paper.

## **2.2. Problems of methodology**

In the last decade problems of food security have been actively explored and significant results have been obtained, especially by FAO. Only in a few works, however, is panel data analysis used as an econometric tool for the full sample of developing countries (Jenkins, Scanlan, 2001; Mihalache-O'keef, Quan, 2011; Austin, McKinney, 2012). If regional comparisons are made, for example, in the Africa regions, where the number of countries in the sample is limited, the analysis of the panel data has a number of estimation problems. Phillips, Moon (2000) and Im, Pesaran (2003), identify two key problems of using fixed-effects or random-effects estimators with panel time-series datasets: the need for slope coefficients to be heterogeneous and the concern of nonstationarity. In our work we develop a methodology of statistical research of food security,

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<sup>8</sup> The State of Food Insecurity in the World, 2015 (FAO). Available at: <http://www.fao.org/3/a-i4646e.pdf>

<sup>9</sup> in place cited

taking into account existing FAO data and use panel cointegration (Hamilton, 1994) as an econometric tool. This approach will be described in more detail in the methodology section.

In most of the studies in the literature review, the authors analyse the possible factors influencing food security in a single country in one year. When using panel data (several countries, several years), the main conclusions also emphasize the influence of this or that factor. The analysis of trends, the ability to manage these trends, and an analysis of relationships over the long-term were not considered. Our approach is based on panel cointegration allowing such analyses. This approach is an extension of standard panel analysis, which allows the analysis of long-run dynamics. This analysis, the comparison of short-run and long-run relationships, the conclusions regarding reactions to shocks and the analysis of damping periods contributes to field.

### **2.3. How to measure food security**

According to FAO<sup>10</sup> food security is determined by the conditions when “all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life”. Food security issues are particularly acute in developing countries, where there are still large numbers of hungry people. Malnutrition is defined as “a condition characterized by the inability to obtain a sufficient amount of food, defined as a level of food consumption that is insufficient to meet dietary energy requirements and lasting at least one year”. Hunger and chronic malnutrition are used as synonyms. However, the proportion of undernourished people is just one dimension of food security. For a comprehensive assessment of food security in the countries of the world since 1996, FAO is using a set of 30 indicators which are classified according to four dimensions: availability, access, utilization and stability<sup>11</sup>.

The indicators of *availability* describe production volumes and productivity, inventory levels and losses, *access* covers economic opportunity to purchase food and transport (the percentage of paved roads, the density of the total road network, GDP per capita, and others.). *Utilization* assesses the consumption of products in terms of nutritional value standards for calories, protein, micronutrients, and *stability* characterizes the situation with enough food in the country in different periods (cereal import dependency ratio; the volatility of food prices in the country, etc.).

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<sup>10</sup> The State of Food Insecurity in the World 2015(FAO). Available at: <http://www.fao.org/3/a-i4646e.pdf>

<sup>11</sup> Food security indicators (FAO). Available at: <http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/#.V2Qip-pv7IV>

The full list of food security indicators used by FAO, is given in Appendix 1. According to FAO, in North Africa it was able to quickly make progress in overcoming hunger, and in countries in sub-Saharan Africa, progress has been very slow. Despite the declining share of hungry people and the increasing energy value of food, a number of problems associated with the quality of the diet remain. In the countries of South Asia and sub-Saharan Africa, for example, the phenomenon of *hidden hunger* can occur when, due to the lack of or inadequate consumption of nutrients various manifestations of malnutrition appear (such as anaemia, vitamin A deficiency, low body weight among children). That is why it is important to study and measure food security in different directions.

The empirical research on the problems of food security usually uses different indicators as a measure of food security. These include the average daily calorie consumption per capita; the percentage of infants weighing less than 2500 grams at birth; the proportion of food consumed containing starch (Poleman (1997)), daily per capita energy consumption and daily per capita protein consumption (Jenkins, Scanlan (2001), Mihalache-O'keef, Quan (2011)), the percentage of undernourished (Austin, McKinney (2012)). Thus, there is no consensus today among researchers, which indicator is best used as a measure of food security. In our study, the cereal import dependency ratio (CIDR) was selected as a measure of food security. Justification for this choice will be given in the results section.

### **3 Hypotheses**

In this section, the hypotheses regarding food security factors are formulated. The proposed hypotheses are based on the theoretical concepts presented in the literature review and on the study of the current socio-economic situation in the countries of North Africa.

**Hypothesis 1. Agriculture and population.** An increasing growth rate in agricultural production and a reduction in demographic population growth is accompanied by an improvement of food security.

This hypothesis follows from the theories of neo-Malthusian population pressure and ecological evolutionary processes. However, reverse general trends are possible. The growing population requires increasing food, which is accompanied by the development of agriculture and leads to economic growth and improvement of the situation with food security (as in, for example, Ghana).



**Hypothesis 2. International trade.** There is a long-term stable trend between international trade flows and food security indicators, however, in the short-term, it is ambiguous and cannot be estimated definitely.

The development of trade has a positive effect on food supply in a country. However, a negative effect on food security is associated with the uncertainty of external trade flows. It can lead to food shortages in the future and jumps in food prices, a decline of domestic food markets, and an increase in the country's economic dependence on food imports.

**Hypothesis 3. FDI.** FDI and food security have potential general trend.

However, this effect is ambiguous. The two theories discussed in the literature review section on effect of FDI on food security (modernization and economic dependency) give conflicting conclusions.

**Hypothesis 4. The financial system.** There is a strong long-term relationship between financial system indicators and food security. The weak development of the banking and finance system corresponds to a low potential of food security. The globalization of the financial system is accompanied by an exacerbation of food security risks.

The financial system is important in the context of food security. Terms of investment and financing, loans, food distribution, etc. all require well-developed financial institutions.

## 4 Data and methodology

### 4.1 Data

We used data from FAO<sup>12</sup> and The World Bank<sup>13</sup> for African countries in accordance with the FAO classification of Africa regions: North Africa, Central Africa, Southern Africa, East Africa, West Africa. In this paper, food security issues in North Africa for the period 1991-2014 are explored. 7 countries were included in the study sample: Algeria, Egypt, Libya, Morocco, Sudan, Tunisia, Western Sahara.

For a comprehensive analysis we used food security and socio-economic development indicators in several groups of characteristics: agricultural production and resources, foreign trade

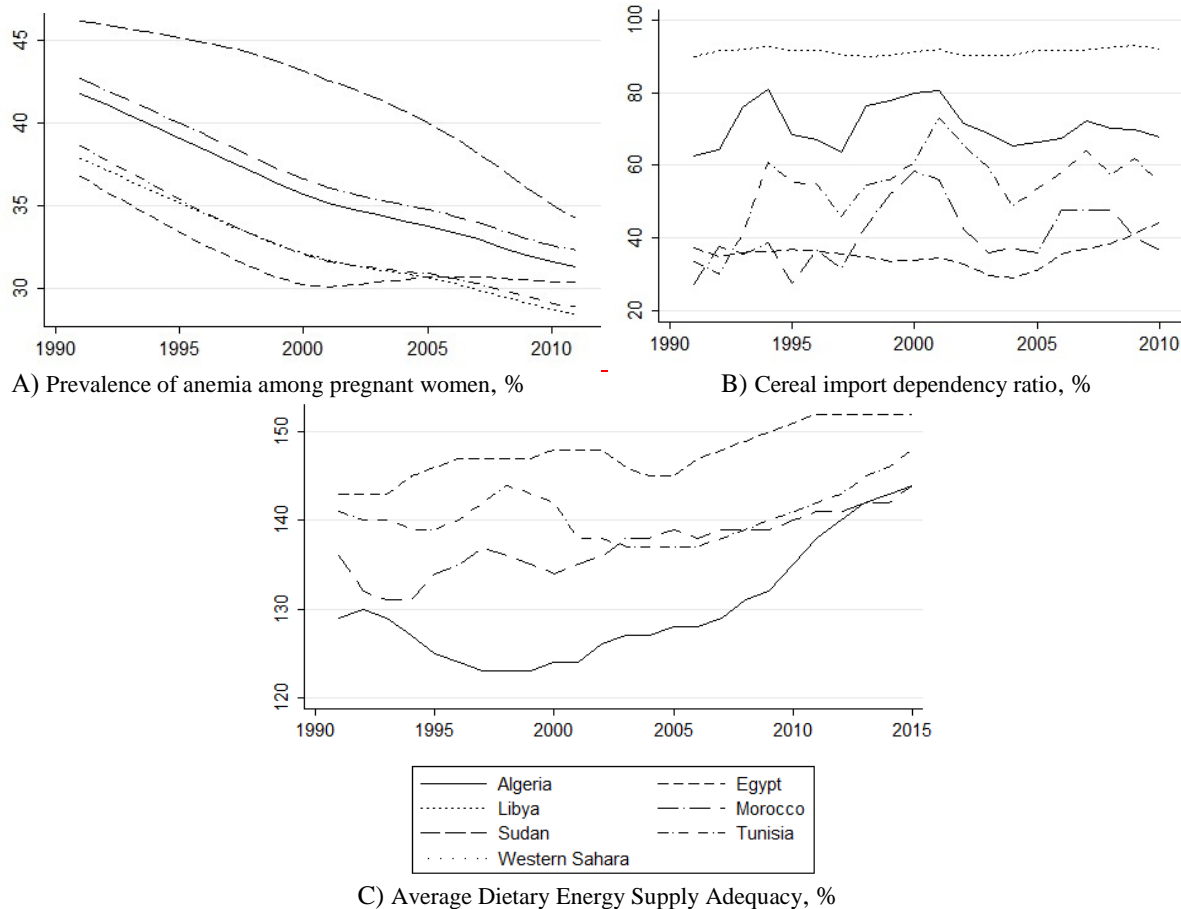
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<sup>12</sup> FAOstat. Available at: <http://faostat3.fao.org/download/I/IC/E>

<sup>13</sup> The World Bank Data. Available at: <http://data.worldbank.org/indicator>

and investment, and the financial system. Table 1 shows the descriptive statistics for the region of North Africa, 1991-2014.

The FAO system of indicators outlined above was taken as a basis of food security measurement. It reflects four aspects of food security: availability, access, utilization and stability<sup>14</sup>. A complete list of indicators and its classification according FAO methodology is provided in Appendix 1.



**Fig. 1. Dynamics of some Food security indicators (North Africa)**

Source: FAO

The dynamics of some indicators are presented in Figure 1 and describe different aspects of food security. The amount of food consumed, expressed as *average dietary energy supply adequacy* exceeds 100% of the daily diet. This indicates that the population of North Africa, on average are not starving: the proportion of hungry people in these countries according to FAO is less than 5% of the population after 2011. The prevalence of anaemia among pregnant women may indicate the quality of consumed food. This indicator considerably decreased during the study period and after 2011 was less than 35%. A fairly large variation in CIDR is observed. Algeria demonstrates the

<sup>14</sup> Food security indicators (FAO). Available at: <http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/#.V2Qip-pv7IV>

highest rates (over 90%) and Egypt the lowest (less than 40%). This has a negative impact on food security. On the whole, positive dynamics are observed both in the quality and quantity of diets. This suggests that measures to improve food security in North Africa are effective and this experience is useful for the study.

Following the World Bank's methodology<sup>15</sup> the financial system characteristics of the *Global Financial Development Database*<sup>16</sup> were divided into four groups:

- depth (the size of financial institutions and markets);
- access (the degree to which individuals can and do use financial services);
- the efficiency and stability of financial institutions (banks and nonbank financial institutions);
- financial markets (stock market, bond market, and other markets).

The analysis of the relationships between food security and the activities of banking and financial institutions are also based on the World Bank's methodology, focused on long-term investment strategies in Africa.

**Table 1. Indicators (North Africa, 1995-2014)**

Variable	Code	Obs	Mean	Std. Dev	Min	Max
<b>Food security</b>						
Average Dietary Energy Supply Adequacy %	ADESA	100	138.92	7.65	123	152
Prevalence of undernourishment, %	PoU	100	5.76	1.17	5	9.2
Depth of the food deficit, %	DoFD	100	28.29	17.93	3	62
Cereal import dependency ratio, %	CIDR	100	58.55	21.62	27.1	93
Value of food imports over total merchandise exports, %	VoFI	112	19.33	14.98	3	69
Per capita food production variability, Const 2004-2006 thousand international \$ per capita	PVpc	140	14.05	15.46	0	64
Percentage of population with access to improved water sources, %	AIW	131	82.24	12.98	54.9	99.2
Percentage of population with access to sanitation facilities, %	ASF	144	73.64	24.08	22.5	96.6
Prevalence of anemia among pregnant women, %	PoAPW	126	35.21	4.59	28.4	46.2
Prevalence of anemia among children under 5 years of age, %	PoACh	126	41.57	16.61	23.9	87.7
<b>Economic Development and recourses</b>						
Agricultural area	AA	141	19345.12	19044.26	2643	112702
Population, Total	POP	138	2.92·10 <sup>7</sup>	2.1·10 <sup>7</sup>	4359515	8.21·10 <sup>7</sup>
GNP, Current USD	GNP	123	6.28·10 <sup>10</sup>	5.42·10 <sup>10</sup>	6.19·10 <sup>9</sup>	2.65·10 <sup>11</sup>
GDP per capita (Constant 2005 USD)	GDPpc	130	2502.52	2003.38	458.64	9099.07
Net per capita Production Index Number (2004-2006 = 100)	PINc	138	99.4567	20.3942	62.89	166.30
<b>International trade</b>						
Import Value Index (2004-2006 = 100)	Imp	92	122.52	78.94	38.00	385.00
Export Value Index (2004-2006 = 100)	Exp	92	106.02	92.76	29.00	425.00
<b>Investmrent to agriculture</b>						

<sup>15</sup> Global Financial Development Report 2013 (WB). Available at: <http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTGLOBALFINREPORT/0,,contentMDK:23267383~pagePK:64168182~piPK:64168060~theSitePK:8816097,00.html>

<sup>16</sup> Global Financial Development Database (GFDD). Available at: <http://www.worldbank.org/en/publication/gfdr/data/global-financial-development-database>

Total Credit, US\$	TCr	51	30547.36	26347.02	37.04	83619.84
Credit to Agriculture, Forestry and Fishing	ACr	51	890.74	484.04	2.12	1771.30
Development Flows to Agriculture, Commitment	DFAC	124	97.31	121.55	0.03	562.81
Development Flows to Agriculture, Disbursement	DFAD	122	40.96	55.93	0.01	400.50
Foreign Direct Investment, inflows	FDI	117	1293.38	1581.96	-270.95	9467.74
Foreign Direct Investment, outflows	FDO	117	199.74	519.39	-480.31	3609.07
Foreign direct investment, net inflows (BoP, current US\$)	INVEST	140	1.35E+09	1.87E+09	-4.83E+08	1.16E+10
<b>Financial System</b>						
Private credit by deposit money banks to GDP, %	pcrdbgdp	127	29.5	22.27	1.68	74.5
Stock market capitalization to GDP, %	stmktcap	66	27.8	23.19	3.96	88.7
Liquid liabilities to GDP, %	llgdp	127	54.6	26.46	8.22	119.4
Central bank assets to GDP, %	cbagdp	127	9.3	11.12	0.10	50.5
Bank credit to bank deposits, %	bcbd	138	65.9	35.74	15.93	148.2
Loan from non- resident banks to GDP, %	nrbloan	114	6.8	5.21	0.61	28.3
Offshore bank deposits to domestic bank deposits, %	offdep	114	14.9	15.13	3.65	91.4
Remittance inflows to GDP, %	remit	121	3.9	2.73	0.03	14.5
Domestic credit to private sector to GDP, %	dcps	138	31.2	22.79	1.62	76.2
Bank lending-deposit spread	blds	69	4.7	1.86	0.50	8.7
Credit to government and state owned enterprises to GDP,%	cgs	135	15.6	12.66	0.12	46.4
Stock market turnover ratio, %	smtr	66	19.5	14.40	3.98	59.2
Bank Z-score	bzs	90	21.7	13.49	-1.04	64.4
Stock price volatility	spv	42	16.9	9.39	4.34	40.1
Bank concentration, %	bc	94	80.3	13.55	44.77	100.0
Consolidated foreign claims of BIS reporting banks to GDP,%	cfc	138	12.2	9.78	0.41	35.8
Foreign banks among total banks, %	fb	95	33.5	16.52	0.00	60.0
Consumer price index (2010=100, average)	cpi	128	75.6	34.83	0.59	258.9

## 4.2 Methodology

As noted in Section 2.2, to check the hypotheses we used panel cointegration, which is based on the determination of long-term relationship of nonstationary random processes, stationary in the first differences (I(1) processes). This approach was implemented in several stages.

**Stage 1. Panel unit-root test.** Initially, the nonstationary process had to be determined. At the first stage, for each indicator panel unit-root tests were carried out at 10% significance level. The results of the tests give the basis for cointegration analysis, which requires variables of the same order to be integrated. We considered five tests: the Levin-Lin-Chu unit-root test (LLC) (Levin, Lin, Chu, 2002), the Breitung unit-root test (Breitung, 2000; Breitung, Das, 2005), the Im-Pesaran-Shin unit-root test (IPS) (Im, Pesaran, Shin, 2003), Fisher-type unit-root tests based on augmented Dickey-Fuller tests (ADF-Fisher) and based on Phillips-Perron tests (PP-Fisher) (Choi, 2001), all three modifications (with a constant, trend, constant and trend). All tests have as the null hypothesis that all the panels contain a unit root. The decision about the stationarity was accepted, if the hypothesis of a unit root was rejected at 10% level for all modifications for three or more statistics. For conflicting testing results, priority was given to group average statistics in favour of the reliability of the conclusion.

**Stage 2. Panel cointegration test.** To further explore the long-run relationship between indicators, the existence of cointegrating relationships between time series must first be determined. At the second stage Pedroni cointegration tests were carried out for a time series that were the realization of I(1). Pedroni (1999, 2004) introduced seven test statistics that test the null hypothesis of no cointegration in nonstationary panels. The seven test statistics are grouped into two categories: group-mean statistics that average the results of individual country test statistics and panel statistics that pool the statistics along the within-dimension. Nonparametric ( $\rho$  and  $t$ ) and parametric (augmented Dickey–Fuller (ADF) and  $v$ ) test statistics are within both groups. The null hypothesis of no cointegration is rejected at 10% significance level, and the decision about the cointegration of processes was accepted, if the hypothesis was rejected for 3 or more statistics out of 7.

**Stage 3. Long-run cointegrating relations.** At the third stage, the expected long-term relations were analysed for cointegrated variables, the assumptions of which were set out in section 3. Multivariate cointegration was also tested by the Fisher-Johansen test. Each cointegrating relation contained three endogenous variables and a constant.

$$y_{1it} = \alpha_i + \beta_1 y_{2it} + \beta_2 y_{3it} + \varepsilon_{it}, \quad (1)$$

where  $y_{1it}, y_{2it}, y_{3it}$  are the values of the indicators for country  $i$  in year  $t$ ;  $\varepsilon_{it}$  is the error of cointegration;  $\alpha_i$  are coefficients corresponding to individual effects;  $\beta_k$  are components of cointegrated vectors.

The evaluation of the parameters for cointegrating equations was carried out using Dynamic Ordinary Least Squares (DOLS) (Kao, 2000) with automatic selection of the auxiliary lags number of  $y_{1it}$  applying Schwarz criterion. Standard errors were calculated using the New-West formula adjusted for heteroscedasticity and autocorrelation<sup>17</sup>.

**Stage 4. Short-run cointegrating relation.** The final step was the estimation of the short-run relation based on the error correction model using panel data in the form of the equation (2).

$$\Delta y_{1it} = \alpha_i^{(\Delta)} + \beta_1^{(\Delta)} \Delta y_{1it-1} + \beta_2^{(\Delta)} \Delta y_{2it-1} + \beta_3^{(\Delta)} \Delta y_{3it-1} + \delta_1^{(\Delta)} \text{ECM}_{it-1} + \varepsilon_{it}^{(\Delta)}, \quad (2)$$

where  $\Delta y_{jit} = y_{jit} - y_{jit-1}$   $j=1,2,3$  are increments of the related indicators;  $\alpha_i^{(\Delta)}$  are coefficients characterizing the individual effects;  $\text{ECM}_{it-1}$  is the adjustment mechanism equilibrium,

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<sup>17</sup> In the case of estimating the cointegration equations, the residuals were not tested additionally, since the specification of cointegration equation corresponded to the test equation in the cointegration test which was conducted earlier.

which are the residuals of the cointegrating equations (1);  $\delta_1^{(\Delta)}$  is a coefficient which characterizes the recovery rate of the equilibrium state for  $y_{1it}$ ;  $\beta_k^{(\Delta)}$  are regression coefficients;  $\varepsilon_{it}^{(\Delta)}$  is a regression error. The estimation of the short-term relation parameters was carried out according to a method of Panel Least Squares, followed by residuals diagnostics. The residuals of the model were checked for autocorrelation with the Wooldridge test for serial correlation in panel data (Wooldridge, 2002). To test the residuals for normality, a panel test was used, which extends the classical Bera-Jarque normality test for panel data (Galvao, 2013 ). The test results indicated the adequacy of obtained models.

## 5 Results

This section presents the results and discussion of various estimation processes.

### 5.1. Panel unit-root tests

Different types of unit root tests, described in section 4, were used to determine the stationarity level of the data series. Table 2 shows test results (statistics and P-value) for CIDR in the countries of North Africa considering the individual effects. The results in Table 2 indicate that the null hypothesis of the unit root cannot be rejected for CIDR at 1% significance level in three out of four tests, and the null hypothesis is rejected for the index  $\Delta$ CIDR (in first differences) at 1% significance level in all tests. These results allow us to conclude that the CIDR is the realization of a nonstationary process, integrated of the first order.

**Table 2. Panel unit-root tests for Cereal import dependency ratio ( North Africa)**

indicators	CIDR		$\Delta$ CIDR	
	Statistic	P-value	Statistic	P-value
LLC	-1.0149	0.1551	-3.0195	0.0013
IPS	-2.9406	0.0016	-5.1711	0.000
ADF-Fisher	24.7113	0.0059	44.0787	0.000
PP-Fisher	18.4659	0.0476	45.0562	0.000

Note:  $\Delta$  - indicate first difference.

The results of the unit root testing of all indicators are given in Appendix 2 (column “stationarity”). All indicators of food security and most of the other variables selected for analysis were nonstationary, integrated of the first order I(1). This result indicates that the processes are in development, which should contribute to progress in improving the lives of the poor.

## 5.2. Panel cointegration test

Pedroni tests are used to determine the cointegrating relationships between time series, which are necessary for further study of long-term dependency. In Table 3 the results of the Pedroni cointegration tests for CIDR and net per capita production index number (PINC) are shown.

**Table 3. Pedroni cointegration tests for CIDR and PINC (North Africa)**

Test statistics		Variables	CIDR and PINC	
			Statistics	P-value
Panel statistics	v-St		2.0828	0.0186
	rho-St		-1.3053	0.0959
	PP-St		-2.1649	0.0152
	ADF-St		-3.1329	0.0009
Group-mean statistics	rho-St		-0.1432	0.4431
	PP-St		-1.3557	0.0876
	ADF-St		-1.6046	0.0543

Note: The null hypothesis is that there is no cointegration.

The Pedroni cointegration test results for the other indicators are given in Appendix 2. The table contains the statistics, for which the null hypothesis of no cointegration was rejected at 10% significance level. On the basis of these results the relationships between the indicators were analysed. An analysis of the table of cointegrating relations in Appendix 2 also produced an important conclusion regarding which index to select as the proxy of food security. These calculations revealed the interaction distribution of the indicators and identified those which accumulate the highest number of connections, and can be used as integral indicators in further analysis. According to the Pedroni cointegration test results the CIDR had the largest number of connections with the economic characteristics and, therefore, it was selected as the integral indicator of food security.

## 5.3. Long-run and short-run relationships

Having established the existence of cointegrating relationships between CIDR and PINC, as well as other indicators according to the hypotheses, we can proceed to the estimation of the long-run and short-run relationships in the form of equations (1) and (2) respectively. A summary of the estimation results of the model (1) for all hypotheses is given in Table 4, which contains the results of cointegrating equations (CE) of CIDR with groups of indicators and the results of the error correction model (ECM) estimations in accordance with the hypothesis. CE with individual effects are presented. The results show that CE parameter estimates are significant (1%, 5% or 10% level), which confirms the presence of long-term relationships. The significance of the negative coefficient

estimates at ECM(-1) in ECM verifies this fact for all equations. The significant and positive estimates at the lags of the absolute growth of CIDR\_D(-1) in all equations, except one (Hyp. 2), indicate the inertial variability of CIDR and this should be taken into account in forecasting. This fact in addition to a low coefficient of determination in ECM points to the need for further analysis in identifying the factors of CIDR dynamics.

**Table 4. The results of evaluation of long- and short-term relation between Cereal import dependency ratio and groups of factors of socio-economic development (North Africa).**

Hypothesis	CE				ECM		
	Variable	Coefficient	R <sup>2</sup>	Trend	Variable	Coefficient	R <sup>2</sup>
Hypothesis 1			0.98	trend	CIDR_D(-1)	0.2047**	0.33
	PINC	-0.5880***			PINC_D(-1)	-0.1814***	
	POP	12.567***			POP_D(-1)	0.8524	
					ECM(-1)	-0.7902***	
Hypothesis 2			0.95	trend <sup>2</sup>	CIDR_D(-1)	0.2614	0.31
	IMP	0.1251***			IMP_D(-1)	0.0159	
	EXP	-0.0971***			EXP_D(-1)	0.0322	
					ECM(-1)	-1.1026***	
Hypothesis 3				trend <sup>2</sup>	CIDR_D(-1)	0.2902***	0.28
	FDI	0.0041**	0.96		FDI_D(-1)	0.0005	
	FDO	-0.0010			FDO_D(-1)	0.0001	
					ECM(-1)	-0.7059***	
Hypothesis 4	<b>Model 4.1</b>		0.97	trend	CIDR_D(-1)	0.1517	0.18
	PCRDBGDP	-0.8552***			PCRDBGDP_D(-1)	-0.0686	
	BCBD	0.4411***			BCBD_D(-1)	0.1626	
					ECM(-1)	-0.7163***	
	<b>Model 4.2</b>		0.96		CIDR_D(-1)	0.3723***	0.44
	BZS	0.4937**			BZS_D(-1)	-0.1404	
	LLGDP	-0.3362***			LLGDP_D(-1)	-0.1036	
					ECM(-1)	-0.7622***	
	<b>Model 4.3</b>		0.62		CIDR_D(-1)	0.2161*	0.31
	NRBLOAN	1.2317**			NRBLOAN_D(-1)	1.0135*	
FB	0.1961***			FB_D(-1)	-0.0245		
				ECM(-1)	-0.6301***		

Note 1. \*Indicate the p-value is significant at 10% (p<0.1), \*\*Indicate the p-value is significant at 5% (p<0.05); \*\*\*Indicate the p-value is significant at 1% (p<0.01).

Note 2. Number of observations for all models is 92 for the period 1992-2010. Limited sample is associated with missing data in CIDR.

Conclusions for each hypothesis will be formulated separately.

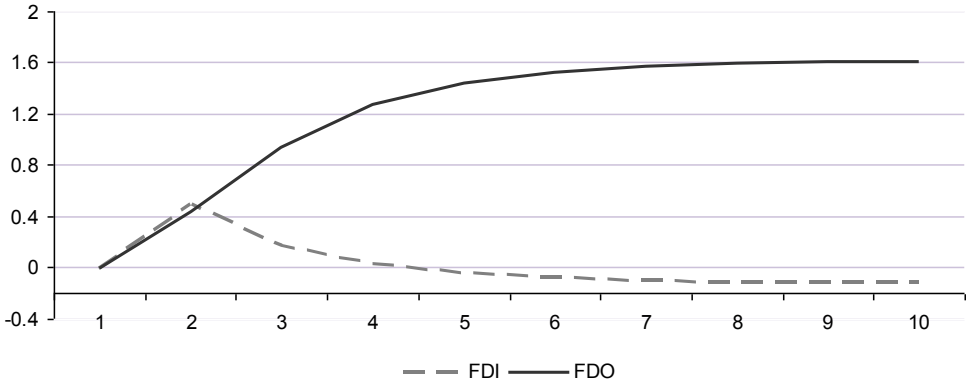
**Hypothesis 1.** At 1% significance level the hypothesis of the presence of a long-term trend for demographic factors and CIDR is not rejected. CIDR increases with the population which is a negative trend for food security. In the short term such a relationship is not apparent. At the same level of significance, we can conclude that the growth rate of agricultural production in the region is accompanied by a stabilization of food security (the negative sign of the coefficient indicates a decline of CIDR). The coefficient at ECM is significant at 1% level and has the correct sign (in the



case of cointegration, negative), which indicates that the adjustment of CIDR in its deviation from the equilibrium trajectory takes place after about 1 year and a quarter ( $1/0.7902$ ).

**Hypothesis 2.** The hypothesis of the existence of long-term equilibrium between import (export) and CIDR is not rejected at 1% significance level. With the growth of CIDR, export growth falls. Given that imports and exports grow in the region, these calculations indicate the need for a global measure for restructuring foreign trade. The insignificance of ECM estimates corresponds to the assumption of the ambiguity in short-term relationships.

**Hypothesis 3.** The hypothesis of the long-term relationship between CIDR and FDI is not rejected at 5% significance level. CIDR increases in the long-term with an increase in FDI. This effect can be considered as negative, because the state of food security is deteriorating and the theory of economic dependence is confirmed. Considering the short-term effects, the results show that the changes in FDI in the short term are not significant. Based on the estimates of model parameters for the food security indicator impulse response functions were calculated (Fig. 2). It allows an assessment of the impact of a single error change (shock) at a rate of one standard deviation and characterizes the mechanisms of short-term adjustments to the equilibrium state.



**Fig. 2. Responses of cereal import dependency ratio on the impulse FDI.**

Fig. 2 shows that the responses of CIDR on the impulse FDI (inflows and outflows) have different behaviour. CIDR initially increases in response to shocks of FDI inflows, but after 4 years there is a loss of reaction (to zero). After 5-6 years an indicator reduction is observed which in the context of food security is a positive effect because it slightly decreases CIDR. The opposite reaction is observed in response to shocks of FDI outflows. In this case, the CIDR increases gradually in 6-7 years by an average of 1.6% and then remains at the new, higher level. These results confirm the long duration of the analysed processes. The detection of the long-term effects of

FDI indicates that investments will only be seen as significant over the long-term. This fact also points to the necessity of improving the investment policy and to raise the role of domestic assets.

**Hypothesis 4.** The hypothesis of the presence of a long-term relationship between the integrated food security index and indicators of financial system's efficiency and stability is not rejected at 1% significance level. With an increase of private credit by bank deposits to GDP CIDR grows. With an increase of bank credits to bank deposits it declines. This indicates the positive role of banks in food security. An increase of a bank's Z-score as a measure of bank solvency is accompanied by a growth of CIDR. This indicates the presence of reserves in the banking system and the need for a detailed analysis of its activities. There is a long-term tendency in the integrated food security index and financial system globalization indicators. A significant long-term relationship between CIDR and the number of loans in non-resident banks, and the number of such banks, is revealed. An increase in non-resident banks is accompanied by the growth of CIDR. Therefore, the hypothesis that the globalization of the financial system exacerbates the food security problems is confirmed.

## 6 Conclusion

Food security is the basis of economic and political stability of any country. In the present study the relationships between food security and economic and financial indicators were analysed using the example of North Africa.

It was found that for this region the development of domestic production in agriculture plays an important role in enhancing food security potential. It was shown that CIDR increases over the long-term with the development of demographic factors, labour productivity, the import flows of agricultural products, FDI and financial system globalization. Export flows of agricultural products, the solvency and sustainability of the banking system have the opposite effect. The study also revealed that in the short-term the relationship between the factors mentioned above is ambiguous. Therefore the strategy of the long-term investment policy pursued by the World Bank and FAO to combat hunger and poverty is justified.

The results of this research can be applied in statistical methodology for the monitoring economic policy in Africa in the sustainable development framework. The analysis proved the main advantage of using econometric tools, based on panel cointegration to obtain statistically reliable conclusions about the identified patterns and to conduct a thorough comparative analysis of similar results in other regions of Africa.

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**Food security indicators (FAO)<sup>18</sup>****AVAILABILITY**

- Average dietary energy supply adequacy
- Average value of food production
- Share of dietary energy supply derived from cereals, roots and tubers
- Average protein supply
- Average supply of protein of animal origin

**ACCESS**

- Percent of paved roads over total roads
- Road density
- Rail lines density
- Gross domestic product per capita (in purchasing power equivalent)
- Domestic food price index
- Prevalence of undernourishment
- Share of food expenditure of the poor
- Depth of the food deficit
- Prevalence of food inadequacy

**STABILITY**

- Cereal import dependency ratio
- Percent of arable land equipped for irrigation
- Value of food imports over total merchandise exports
- Political stability and absence of violence/terrorism
- Domestic food price volatility
- Per capita food production variability
- Per capita food supply variability

**UTILIZATION**

- Access to improved water sources
- Access to improved sanitation facilities
- Percentage of children under 5 years of age affected by wasting
- Percentage of children under 5 years of age who are stunted
- Percentage of children under 5 years of age who are underweight
- Percentage of adults who are underweight
- Prevalence of anaemia among pregnant women
- Prevalence of anaemia among children under 5 years of age
- Prevalence of vitamin A deficiency in the population
- Prevalence of school-age children (6-12 years) with insufficient iodine intake

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<sup>18</sup> Source: <http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/#.V2rszVNv7IU>

## Panel unit-root tests and Pedroni cointegration tests: main results

	Stationarity	Pedroni cointegration tests*									
		ADESA	PoU	DoFD	CIDR	VoFI	PVpc	AIW	ASF	PoAPW	PoACh
PiNc	I(1)	6			6			6	4		
GDPpc	I(1)				6			6	4		4
GNP	I(1)				6	3	4				
GDPc	I(1)		3		5		4				
Pop	I(1)				5						
Aa	I(1)	3			5	3		5	5		
Imp	I(1)			4	6	5	5	6	4		
exp	I(1)	4		5	6			4			
TCr	I(1)							5			4
ACr	I(1)	3	4	4				4	5		5
DFAC	I(0)	3			5	3	3				
DFAD	I(1)				4		3	4			
FDI	I(1)	3			6			5			4
FDO	I(1)				6			5			4
INVEST	I(1)				5						
pcrdbgdp	I(1)	4			5			4	4		
stmktcap	I(1)			3							3
llgdp	I(1)				4	4		3			
cbagdp	I(1)				4			4			
bcbd	I(1)	4	5	4	6			5	4	5	5
nrbloan	I(1)		3	3	4		4				4
offdep	I(1)		3	3	4			3		4	3
remit	I(1)				5			4			
dcps	I(0)	5		3	5	5	4	5	4		3
blds	I(1)	5						4			
cgs	I(1)	5	6	6	6	5		5	4	4	3
smtr	I(1)	5	4	5	5		5	5	5	5	5
bzs	I(1)	4			4		5	5	4		3
spv	I(1)	4		4		4		4	5		4
bc	I(0)	6	4	3	5	5		6	6	6	6
cfc	I(1)			4	6	4		4			
fb	I(1)	5	4	4	3			3			
cpi	I(2)		3			3		4	3		
pcrdbgdp	I(1)	4			5			4	4		
stmktcap	I(1)			3							3
llgdp	I(1)				4	4		3			
cbagdp	I(1)				4			4			
bcbd	I(1)	4	5	4	6			5	4	5	5
nrbloan	I(1)		3	3	4		4				4
offdep	I(1)		3	3	4			3		4	3

\* **Pedroni cointegration tests:** 7 tests was conducted. In the table the maximum number of statistics are indicated for which Null hypothesis of no cointegration is rejected at 10% significance level.

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