

Analyzing the Relationship between Agricultural Sector Investments and Food Security in Developing Countries: An Econometric Study Using Cointegration Models

تحليل العلاقة بين استثمارات القطاع الزراعي والأمن الغذائي في الدول النامية: دراسة قياسية باستخدام نماذج التكامل المشترك

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Abstract:

This study aims to analyze the relationship between agricultural sector investments and food security in developing countries during the period 2000–2023. Panel data was adopted and a vector error correction model (Panel VECM) was used to measure both the long-term relationship and short-term dynamics between the variables. The database included key indicators such as agricultural investments and the food security index, in addition to control variables represented by the value added of agriculture (% of GDP), the ratio of agricultural employment to the total labor force (EMPL_ARG), and the ratio of arable land to total area (LD_AGR). The results showed a complementary and dynamic relationship between agricultural investments and food security, with investments contributing to higher productivity and more equitable food distribution, while improved food security acts as an incentive to attract more investments to the agricultural sector, supporting the path sustainable agricultural development. These results confirm the pivotal role of agricultural investments in achieving long-term food security, as well as the reciprocal effect that enhances sustainable development in developing countries.

Keywords: Agricultural Investments; Food Security; Developing Countries; Panel Vector Error Correction Model (Panel VECM).

JEL Classification Codes: Q14 ; Q18 ; O11 ; C33.

ملخص:

تهدف هذه الدراسة إلى تحليل العلاقة بين استثمارات القطاع الزراعي والأمن الغذائي في الدول النامية خلال الفترة 2000–2023. وقد تم اعتماد بيانات بانل وتوظيف نموذج تصحيح الخطأ الموجه (*Panel VECM*) لقياس كل من العلاقة طويلة الأجل والديناميكيات قصيرة الأجل بين المتغيرات. شملت قاعدة البيانات مؤشرات رئيسية مثل الاستثمارات الزراعية، ومؤشر الأمن الغذائي، إضافة إلى متغيرات ضابطة تتمثل في القيمة المضافة للزراعة (% من الناتج المحلي الإجمالي)، نسبة العمالة الزراعية من إجمالي القوى العاملة (*EMPL_ARG*)، ونسبة الأراضي الصالحة للزراعة من إجمالي المساحة (*LD_AGR*)، أظهرت النتائج وجود علاقة تكاملية وديناميكية بين الاستثمارات الزراعية والأمن الغذائي، حيث تسهم الاستثمارات في رفع الإنتاجية وتحقيق توزيع أكثر عدالة للغذاء، في حين يشكل تحسن الأمن الغذائي حافزاً لجذب مزيد من الاستثمارات نحو القطاع

الزراعي، بما يدعم مسار التنمية الزراعية المستدامة. وتؤكد هذه النتائج الدور المحوري للاستثمارات الزراعية في تحقيق الأمن الغذائي على المدى الطويل، وكذلك الأثر التبادلي الذي يعزز استدامة التنمية في الدول النامية.

كلمات مفتاحية: استثمارات زراعية أمن غذائي ؛ دول نامية ؛ نموذج تصحيح الخطأ الموجه (Panel VECM).

تصنيفات JEL : Q14 ؛ Q18 ؛ O11 ؛ C33 .

INTRODUCTION:

Developing countries are increasingly confronted with difficulties in achieving food security as a result of rapid population expansion, climate change, and fragile production systems. The agricultural sector remains a key driver of both economic and social development, providing employment for a large share of the population and serving as a significant source of income in many of these economies. Therefore, investing in agriculture is vital for boosting productivity, increasing food supply, and ensuring sustainable access to food.

Although the role of agricultural investment has gained considerable attention in economic and development studies, many developing nations still face structural constraints that limit the sector's performance and its capacity to satisfy the growing demand for food. These constraints include insufficient funding, weak infrastructure, low productivity, limited natural resources, and heightened exposure to climate-related risks. Such factors reduce the sector's effectiveness in contributing to sustainable food security. Consequently, reinforcing agricultural investment has become a strategic necessity—not only to enhance food production, but also to promote economic growth, create job opportunities, and strengthen agricultural value chains, thereby fostering overall development.

Within this framework, public policies are essential in directing agricultural investments and amplifying their economic and social outcomes. This can be achieved by establishing appropriate legal and regulatory systems, facilitating access to financial and natural resources, and improving infrastructure, especially in rural areas. In addition, the adoption of modern technologies and innovative practices—such as climate-smart agriculture, improved inputs, and advanced irrigation systems—plays a central role in raising productivity, increasing competitiveness, and ensuring sustainability amid escalating environmental challenges.

Accordingly, examining the link between the scale and characteristics of agricultural investment and food security levels in developing countries is of strategic importance. Such analysis helps identify the most effective policies and approaches for developing resilient food systems capable of adapting to future challenges and achieving sustainable long-term development. Hence, the research problem can be formulated as follows:

What is the form of the causal relationship between agricultural sector investments and the achievement of food security in developing countries?

Research Importance:

the importance of this study stems from its aim to address a fundamental issue in developing countries, namely the relationship between agricultural sector investments and food security. Food security represents a strategic objective for sustainable development, while the agricultural sector is one of the primary drivers for achieving it, particularly given that a large segment of the population in these countries relies on agriculture as a main source of food and income. The significance of this study can be highlighted in several aspects:

- By employing cointegration models to test the long-run causal relationship between

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agricultural investments and food security, the study contributes to enriching the economic and econometric literature on food security in developing countries.

- The findings of the study assist policymakers in evaluating the effectiveness of investment policies directed toward the agricultural sector and their impact on achieving sustainable food security.
- Considering current global challenges such as climate change, food price volatility, and geopolitical crises, strengthening agricultural investments becomes a priority to ensure food stability.
- The study provides empirical evidence based on data, enabling the formulation of practical and actionable recommendations within the context of developing countries.

1- Literature Review and Previous Studies:

The literature review provides an overview of previous research related to the relationship between agricultural investments and food security, particularly in developing countries. It aims to summarize existing knowledge, highlight key findings, and identify gaps in the literature that this study seeks to address. By examining both theoretical and empirical studies, this section establishes the foundation for understanding how agricultural investment contributes to ensuring food security and guides the formulation of the research model and hypotheses:

1-1 Literature Review

FAO Definition: According to the Food and Agriculture Organization (FAO), food security is defined as “the availability of food for all members of society in sufficient quantity and quality to meet their needs on a continuous basis, ensuring a healthy and active life.” This definition differs from the traditional concept of food security, which focuses on achieving self-sufficiency by relying on a country’s own resources and capabilities to produce its food needs domestically. This distinction aligns more closely with current economic transformations, particularly the liberalization of international trade in food commodities. (Arab Monetary Fund (AMF), 2020).

Historical Perspective of Food Security:Originally, the term "food security" was used to describe a state that has the capacity to access sufficient quantities of food to meet its nutritional energy needs. Some experts have interpreted the concept of food security to mean "self-sufficiency," that is, a country’s ability to produce the food required or demanded by its population. (-Andersen, 2009)

Food Security in Community and Agricultural Context:As highlighted by the study (Choudhury & Azhar Abbas, 2017), food security is linked to the achievement of multiple objectives and depends on social, economic, and physical processes, particularly those related to agriculture. Food security at the community level can be achieved through the effective interaction between these processes and variables, which connect food production to supply chains in order to address issues of food demand and availability from farm to table efficiently. Based on this perspective, four fundamental dimensions of the concept of food security can be identified.

Role of Agricultural Investments in Food Security:Agricultural investments encompass various expenditures aimed at increasing productivity and improving agricultural

infrastructure, whether by the public sector, private sector, or through foreign direct investment. Theoretically, economic literature assumes that increased agricultural investments lead to enhanced agricultural production, which in turn strengthens food availability and stability, with positive implications for economic growth and rural development. (Yao, Alhussam, Abu Risha, & Ahmed Memon, 2020).

Comprehensive Socio-Economic Perspective on Food Security: Food security is a crucial aspect of human well-being that involves multiple socio-economic dimensions. It not only requires that sufficient, safe, and nutritious food be available and accessible to all individuals at all times but also emphasizes the importance of agricultural investment in achieving this goal. Agricultural investment positively affects food security by boosting agricultural production efficiency, improving infrastructure and technology, and enhancing food supply chain performance. These investments increase crop yields and make food more accessible and affordable, thereby contributing significantly to long-term food security outcomes, especially in developing countries (Zhao & Chen, 2023).

After presenting the key definitions and theoretical concepts related to agricultural investment and food security, it is important to examine how these concepts have been addressed in empirical research. The following section reviews previous studies that have analyzed the relationship between investments in the agricultural sector and food security, highlighting their methodologies, findings, and implications. This review provides a foundation for understanding existing knowledge and identifying gaps that this study aims to address.

1-2 Previous Studies:

Several studies (e.g., (Timmer, (2010))) have indicated that agricultural investment represents one of the most effective forms of investment in reducing poverty and hunger compared to other sectors. (Pawlak & Kołodziejczak, 2020) found that countries experiencing the most severe food security challenges are often those with a large share of agriculture in their GDP, yet they face difficult agricultural production conditions, such as inadequate infrastructure, limited irrigation, insufficient farming equipment, and low capital stock.

Empirical studies in Sub-Saharan Africa, such as (Mwangi & Kariuk, 2015), reported that increased government expenditure on agriculture was positively associated with improvements in the food self-sufficiency index. In the Arab world, studies by (Elbanna, 2018) and (Bencheikh, 2020) showed that agricultural investments contributed to increased agricultural productivity, but they were insufficient to achieve sustainable food security due to the heavy dependence on grain imports.

Other empirical studies employing cointegration models (e.g., (Alexandratos & Bruinsma, 2012) have demonstrated the existence of a long-term relationship between the scale of agricultural investments and improvements in food security indicators. Similarly, (Kamenya , Hendriks, Gandidzanwa, Ulimwengu, & Odjo, November 2022) found that agricultural expenditure had a positive impact on food security indicators in the nine ECOWAS member states (Benin, Burkina Faso, The Gambia, Ghana, Mali, Niger, Nigeria, Senegal, and Togo).

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A review of the literature reveals that most previous studies have either focused on describing the relationship between agricultural investment and food security or on case studies of specific countries. Comparative empirical studies employing cointegration models to examine the causal relationship across a group of developing countries remain limited. Therefore, the present study seeks to address this gap by conducting an empirical analysis of the long-term relationship between agricultural investments and food security in developing countries.

2- Study Methodology

To study the causal relationship between agricultural sector investments and food security in developing countries (Indonesia, Argentina, Jordan, Algeria, Iraq, Niger, Tunisia, Oman, Mali, Egypt, Nigeria, Mauritania) over the period 2000–2023, the Panel Vector Error Correction Model (Panel VECM) was employed. This is a dynamic model that allows testing both long-term and short-term equilibrium relationships among variables within the same equation (Sung, H.M. & Urrutia, J.L., 1995)

Estimating the Panel VECM requires that two fundamental conditions are met: the stationarity of the study variables and their first-order integration, $I(1)$ (Mahembe & Nicholas, 2019). After collecting data for each variable in each country under study, the mathematical specification of the model is determined as follows:

$$FSI = f(FDI_{AGR}, VA_{AGR}, empl_{arg}, LD_{AGR}) \dots \dots \dots (1)$$

To examine this relationship in developing countries, a representative sample of countries was selected to ensure geographical diversity, variation in economic and agricultural development, and availability of reliable data. The analysis focuses on key variables that capture both the level of agricultural investment and the status of food security. To provide clarity on these variables, including their measurement units and data sources, the definitions of each variable are summarized in Table (01):

Table (01): Study Variables

Variable	Unit	Data Source	Description
FSI (Food Security)	%	FAO	Measures the percentage of per capita food production relative to total dietary needs, reflecting the country's ability to ensure adequate food for its population.
VA_AGR (Agricultural Value Added)	% of GDP	World Bank	Share of agriculture in the country's total GDP, indicating the economic contribution of the agricultural sector.
FDI_AGR (Agricultural FDI)	%	World Bank	Represents the share of foreign direct investment flowing into the agricultural sector relative to total FDI, indicating international investment focus on agriculture.
empl_AGR (Agricultural Employment)	%	FAO	Percentage of the total workforce employed in agriculture, reflecting labor reliance on the sector.
LD_AGR (Agricultural Land)	%	FAO	Percentage of total land area that is arable or suitable for agriculture, indicating potential land availability for food production.

Source: Author's own work (worldbank) (FAO, IFAD and UNICEF)

The structural framework can be formulated using PVECM causality in the matrix, as illustrated in Equation (2):

$$\begin{bmatrix} \Delta FSI_{it} \\ \Delta FDI_{AGRit} \\ \Delta VA_{AGRit} \\ \Delta empl_{argit} \\ \Delta LD_{AGRit} \end{bmatrix} = \begin{bmatrix} \alpha_{1j} \\ \alpha_{2j} \\ \alpha_{3j} \\ \alpha_{4j} \\ \alpha_{5j} \end{bmatrix} + \sum_{k=1}^{q-1} \begin{bmatrix} \beta_{11ik}(L)\beta_{12ik}(L)\beta_{13ik}(L)\beta_{14ik}(L)\beta_{15ik}(L) \\ \beta_{21ik}(L)\beta_{22ik}(L)\beta_{23ik}(L)\beta_{24ik}(L)\beta_{25ik}(L) \\ \beta_{31ik}(L)\beta_{32ik}(L)\beta_{33ik}(L)\beta_{34ik}(L)\beta_{35ik}(L) \\ \beta_{41ik}(L)\beta_{42ik}(L)\beta_{43ik}(L)\beta_{44ik}(L)\beta_{45ik}(L) \\ \beta_{51ik}(L)\beta_{52ik}(L)\beta_{53ik}(L)\beta_{54ik}(L)\beta_{55ik}(L) \end{bmatrix} \begin{bmatrix} \Delta FSI_{it-k} \\ \Delta FDI_{AGRit-k} \\ \Delta VA_{AGRit-k} \\ \Delta empl_{argit-k} \\ \Delta LD_{AGRit-k} \end{bmatrix} + \begin{bmatrix} \lambda_{1j}ECT_{it-1} \\ \lambda_{2j}ECT_{it-1} \\ \lambda_{3j}ECT_{it-1} \\ \lambda_{4j}ECT_{it-1} \\ \lambda_{5j}ECT_{it-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1it} \\ \varepsilon_{2it} \\ \varepsilon_{3it} \\ \varepsilon_{4it} \\ \varepsilon_{5it} \end{bmatrix} \dots \dots \dots (2)$$

FSI, FDI_AGR, VA_AGR, EMPL_AGR, and LD_AGR are defined as shown in Equation (1), representing the dependent and explanatory variables. Δ denotes the first difference (I(1)), with $i = 1, \dots, N$ and $t = 1, \dots, T$. The parameters to be estimated are $\lambda_s, \beta_s, \alpha_s$, while ε_{jt} ($j = 1 \dots 5$) represents the white noise. ECT_{it-1} is the error correction term, and λ_s is the speed of adjustment coefficient (error correction term coefficient), indicating the magnitude of change in the dependent variable resulting from a one-unit deviation of the independent variable from its long-run equilibrium value. This coefficient is expected to be negative (Mishra, P. K., 2012). Short-run causality is tested using the lagged dynamic explanatory variables $[\beta_s]$ via the Wald χ^2 statistic (Abraham Wald, 1943), whereas long-run causality is examined through the error correction term coefficients $\lambda_s ECT_{t-j}$.

2-1 Results of Panel Unit Root Tests:

Before estimating the Panel Error Correction Model (Panel VECM), it is first necessary to perform a unit root test on the panel data, and then to verify the existence of cointegration among the various indicators of external trade liberalization and inflation for the countries under study. Recently, several advanced tests have been developed to analyze and test unit roots in panel data, the most prominent with the Levin, Lin, and Chu (LLC) test (Levin, A., Lin, C.-F., & Chu, C.-S. J, 2002) and the Breitung t-stat test, both of which are pooled tests, in addition to the Im, Pesaran, and Shin (IPS) test (Im, K. S, Pesaran, H. M, & Shin, Y. , 2003)). There are also other tests such as the Fisher-ADF test and the Fisher-Phillips-Perron (Fisher-PP) test (Choi, I., 2001). Panel unit root tests differ from unit root tests for individual time series, as they combine both cross-sectional and time-series information together, resulting in more accurate outcomes (John Thornton & Olumuyiwa S. Adedaj, 2006). Based on this, we applied the aforementioned unit root tests to each variable individually, as shown in the following table:

Table (02): Panel Data Unit Root Test

Statistical Tests	Variables									
	(Level)I(0)					(1st difference)I(1)				
	FSI	FDI_AGR	VA_AGR	EMPL_AGR	LD_AGR	FSI	FDI_AGR	VA_AGR	EMPL_AGR	LD_AGR
LLC	23.83 (1.00)	0.70555 (0.7598)	3.9126 (1.000)	0.88967 (0.8132)	0.1979 (0.5784)	-14.34 (0.000)*	9.11040 (0.0000)*	-3.00695 (0.0013)**	-6.1530 (0.000)*	-3.2295 (0.0006)**
Breitung t-stat	3.038 (0.9988)	-1.37115 (0.0852)	0.3528 (0.6379)	- 0.26347	-0.4165 (0.3385)	-9.231	-5.96779 (0.000)*	-1.17487 (0.0120)**	-7.5040 (0.000)*	-10.1292 (0.0000)*

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				(0.3961)		(0.000)*				
IPS	0.81872 (0.7935)	-2.15588 ((0.0155)	-0.0570 (0.4772)	1.45512 (0.9272)	-2.1775 (0.0147)	-18.85 (0.000)*	-4.98724 (0.0000)*	-8.76829 (0.0000)*	-8.7539 (0.000)*	-12.9903 (0.000)*
Fisher-ADF	12.8292 (0.9689)	32.3770 (0.1179)	23.377 (0.4976)	14.5341 (0.9337)	42.798 (0.0050)	246.287 (0.000)*	63.0076 (0.0000)*	117.743 (0.0000)*	110.25 (0.000)*	152.928 (0.000)*

(**)The p-value at the 1 %; 5% significance level.

Source: Prepared by the authors using the statistical software EViews 13

According to the results shown in the above table for the panel data unit root tests, it is evident that the time series of the variables FSI, FDI_AGR, VA_AGR, EMPL_AGR, and LD_AGR are all non-stationary in their levels (Level 0) at the 5% significance threshold, meaning that the null hypothesis of a unit root cannot be rejected. Nevertheless, once the first differences (I(1)) are applied and at the same significance level, the null hypothesis is rejected in favor of the alternative, indicating that no unit root exists. This confirms that all variables are integrated of order one, I(1).

2-2 Results of the Panel Cross-Sectional Residual Dependence Test

The cross-sectional residual dependence (CSD) test is a crucial step when investigating causal links using Granger causality tests for panel data, particularly in studies focused on convergence and integration among the countries included in the study. Any structural shift or unexpected shock in one nation could influence other countries, which may, in turn, affect the outcomes and context of the analysis. Therefore, it is important to conduct multiple tests to minimize bias in estimation results when examining causal relationships among the study variables, especially in dynamic panel models. These tests include the Lagrange multiplier approach of (Breusch & Pagan, 1980)), as well as the methods developed by (Pesaran M. , 2004) and (Pesaran, Ullah and Yamagata).

According to the results presented in Table (03) for the CSD test, the null hypothesis of no cross-sectional correlation among the residuals of the variables within the sample is **rejected**, as the p-values for the Breusch-Pagan LM, Pesaran scaled LM, and Pesaran CD tests are all below the 5% significance level..

Table(03) : Panel cross-sectional residual dependence

Variables	Test	Statistic	d.f.	Prob.
FSI/FDI_AGR /VA_AGR /EMPL_AGR /LD_AGR	Breusch-Pagan LM	1021.058	66	0.0000*
	Pesaran scaled LM	83.12716		0.0000*
	Pesaran CD	28.48797		0.0000*

(*): The p-value at the 5% significance level.

Source: Prepared by the authors using the statistical software EViews 13

After confirming the stationarity of all panel time series at their first differences, indicating that they are I(1), we proceed to the next step, which is to verify the existence of cointegration among the study variables. This indicates the presence of a long-run equilibrium relationship between investments in the agricultural sector and food security during the period from 2000 to 2023.

2-3 Results of the Panel Cointegration Test

Panel data cointegration tests are conducted to determine the existence of a long-run equilibrium relationship among non-stationary variables. The results of these tests affect the strategy for performing Granger causality tests on panel data. Several advanced tests have been developed to verify cointegration in panel data, among the most prominent of which are (-Pedroni) test, the Kao (1999) test, and the Johansen-Fisher test. In this study, we focus solely on the Pedroni test.

Table (04):Pedroni Residual Cointegration Test

Alternative hypothesis: common AR coefs. (within-dimension)

	Weighted			
	Statistic	Prob.	Statistic	Prob.
Panel v-Statistic	0.538179	0.2952	1.528768	0.0632***
Panel rho-Statistic	3.215179	0.9993	1.307892	0.9045
Panel PP-Statistic	-3.060731	0.0011**	-6.781846	0.0000*
Panel ADF-Statistic	-4.221583	0.0000*	-6.104286	0.0000*

Alternative hypothesis: individual AR coefs. (between-dimension)

	Statistic	Prob.	
Group rho-Statistic	2.472735	0.9933	
Group PP-Statistic	-9.889711	0.0000*	
Group ADF-Statistic	-5.502571	0.0000*	

(*) p-value at the 5% significance level.

Source: Prepared by the authors using the statistical software EViews 13.

Based on the results indicating that the existence of cointegration reflects a long-run equilibrium relationship between the independent variable and the dependent variables, a panel data cointegration test at the 5% significance level was conducted for the variables FSI, FDI_AGR, VA_AGR, EMPL_AGR, and LD_AGR, assuming that some variables are dependent while others are explanatory. In this regard, the Pedroni (2004) cointegration test was employed. The results confirm the presence of a cointegrating relationship, i.e., a long-run equilibrium relationship among the variables, as supported by the majority of the test statistics, whose p-values are below the 5% threshold. Consequently, the null hypothesis of no cointegration is rejected at the 5% significance level. Accordingly, the Panel Vector Error Correction Model (Panel VECM) is deemed appropriate for further analysis.

2-4 Granger causality test results based on the Panel Vector Error Correction Model (VECM)

As highlighted in the literature on causality testing in panel data, particularly dynamic models (Granger, C.W.J., 1980), when variables are stationary and integrated of the same order without cointegration, causality can be examined using a Panel VAR model. However, if the variables are stationary and integrated of the same order with the presence of long-run cointegration, a Panel VECM can be applied to test both short-run and long-run causal relationships. This is consistent with the earlier results of the Pedroni cointegration test. Accordingly, a dynamic

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Panel VECM was estimated to conduct the Granger causality test, with the optimal lag length set to lag(2) based on the Schwarz criterion. The following table presents the relevant results:

Table (05) : Panel Vector Error Correction Granger Causality Test

Dependent variable	Direction of causality/explanatory variables					Long run coefficient (t-statistics)
	Short run χ^2 statistics (p-value)					
	ΔFSI	ΔFDI_{AGR}	ΔVA_{AGR}	$\Delta empl_{arg}$	ΔLD_{AGR}	
ΔFSI	-	11.13634 (0.0110)**	0.272991 (0.9650)	1.768466 (0.6218)	4.768973 (0.1895)	-0.0317 (0.0916)***
ΔFDI_{AGR}	8.48065 (0.0371)* *	-	0.928834 (0.8184)	1.798232 (0.6153)	2.238350 (0.5244)	-0.00664 (0.035)**
ΔVA_{AGR}	1.054716 (0.7880)	0.442317 (0.9314)	-	3.162740 (0.3672)	0.547683 (0.9083)	0.00295 (0.1230)
$\Delta empl_{arg}$	4.314328 (0.2295)	8.996750 (0.0293)**	4.613166 (0.2024)	-	1.852713 (0.6035)	-0.0029 (0.1230)
ΔLD_{AGR}	0.245669 (0.9699)	1.250249 (0.7410)	1.165724 (0.7612)	0.583328 (0.9002)	-	-0.00146 (0.0935)***

(*), (**): significance levels of 5% and 10%, respectively.

Source: Prepared by the authors using the statistical software EViews 13.

Based on the results of the Granger causality test derived from the estimation of the Panel Vector Error Correction Model (Panel VECM), as reported in the table above, the results indicate that :

The results indicate that the causality relationships, whether in the short run or the long run, among the study variables—FSI (food security index), FDI_AGR (foreign direct investment inflows into the agricultural sector, %), VA_AGR (value added in the agricultural sector as a percentage of GDP), EMPL_AGR (employment in the agricultural sector as a share of total labor force), and LD_AGR (arable land as a percentage of total land area)—are predominantly long-run relationships. This suggests the existence of a long-term causal linkage between agricultural investments in developing countries and the food security index. We also find a bidirectional relationship between the two variables in both the long run and the short run, whereby the level of food security influences the scale and quality of agricultural investments. When food insecurity increases in developing countries, governments face growing pressure to allocate more public spending and investment toward the agricultural sector in order to enhance productivity and achieve self-sufficiency. In turn, agricultural investments contribute to strengthening food security in these countries, as they constitute a fundamental pillar for its achievement. The greater the investments in production, infrastructure, and technology, the higher the capacity to ensure adequate, safe, and sustainable food supplies for the population. However, the success of these investments requires effective management, supportive policies for smallholder farmers, and measures to adapt to climate change.

According to the empirical results obtained, particularly with regard to the relationship and direction between food security and agricultural investments in developing countries, it is evident that by the end of 2021 global food security was on high alert, especially in African, Asian, and other developing countries. This situation was largely driven by the lingering

effects of the COVID-19 pandemic, in addition to new and ongoing conflicts and climate-related shocks. Moreover, the uneven economic recovery following the sharp contraction in economic activity in 2022 (FAO, IFAD, UNICEF, & WFP and WHO, 2023), along with rising food, fuel, and transportation prices associated with this recovery, hindered any meaningful progress toward improving food security.

Conclusion:

The results of this study indicate that investments in the agricultural sector play a pivotal role in enhancing food security in developing countries. The econometric models based on cointegration tests revealed the existence of a long-run relationship between the volume of agricultural investments and food security indicators, as well as a bidirectional linkage from agricultural investments to food security and vice versa. This confirms that supporting agriculture is not merely a productive economic sector but constitutes a fundamental pillar for ensuring the availability, stability, and accessibility of food.

However, the study also showed that the impact of agricultural investments is not immediate; it requires time and integration with supportive policies in areas such as irrigation, agricultural extension, value chains, and food trade. Achieving this calls for a holistic vision that integrates economic, social, and environmental dimensions to attain sustainable development goals.

Based on the above, it can be concluded that effectively targeted agricultural investments represent a strategic option for developing countries to achieve food security amid global challenges such as population growth, food price volatility, and climate change. Consequently, the study recommends the following:

- Design sustainable agricultural strategies that enhance the resilience of farming systems to climate variability by integrating innovative practices that help mitigate food insecurity, alongside investment in supplemental irrigation technologies within rainfed systems, while considering potential environmental impacts.
- Develop effective agricultural extension systems aimed at guiding smallholder farmers to adopt low-cost, climate-resilient practices that take into account the social and economic specificities of local communities, particularly in least-developed countries and conflict-affected areas.
- Promote agricultural financial inclusion by enabling smallholder farmers to access microfinance services and supporting their integration into food value chains at both local and international levels.
- Innovate sustainable financing tools and mechanisms, such as green bonds directed toward the agricultural sector, to attract investors seeking social and environmental impact alongside economic returns.
- Diversify trade partnerships to reduce the risks associated with price volatility, while promoting the inclusion of agricultural products in preferential trade arrangements, thereby enhancing opportunities for inter- and intra-regional food trade.
- Strengthen regional cooperation frameworks among developing countries in the field of food security through the exchange of resources and expertise and the dissemination of best practices, thus enhancing the capacity of developing countries to achieve shared food security.

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