

Measuring Change in Total Factor Productivity in the Iraqi Agricultural Sector Using the Malmquist Index (1990–2023)

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Abstract

This study aims to measure changes in the total factor productivity of the Iraqi agricultural sector using the Malmquist Productivity Index during the period 1990–2023 by analyzing technical efficiency and technological change. The study relied on annual data for the period 1990–2023. Agricultural gross domestic product (GDP) was used as the output variable, while agricultural fixed capital formation and agricultural labor were used as input variables. The Malmquist Productivity Index was estimated using DEAP 2.1 software to measure changes in technical efficiency (EFFCH), technological change (TECHCH), and total factor productivity (TFPCH). The results showed that the geometric mean of technical efficiency was 0.950, the geometric mean of technological change was 0.732, and the geometric mean of total factor productivity was 0.709, indicating a decline in agricultural productivity during the study period. The decline in technological change reflects the limited adoption of modern agricultural technologies, weak agricultural investment, and the economic and environmental challenges experienced by Iraq during the study period. The study recommends promoting the adoption of modern agricultural technologies, improving agricultural resource management, and increasing investment in the agricultural sector to enhance productivity and support sustainable agricultural development.

Keywords: technical efficiency, Malmquist index, total factor productivity, Iraqi agricultural sector, technical change.

Section 1: Research Methodology and Previous Studies.

Introduction

The agricultural sector is one of Iraq's important economic sectors due to its fundamental role in achieving food security, creating jobs, and supporting gross domestic product. However, over the past decades, this sector has faced numerous economic, technical, and environmental challenges that have directly impacted levels of agricultural productivity and efficiency[3]. Technical efficiency and technological change are

key indicators used to evaluate the performance of the agricultural sector and measure the efficiency of available resource use. Analyzing the total factor productivity of agricultural production helps determine the level of technological development and the efficiency of agricultural production factors, which in turn contributes to supporting agricultural policies and improving production performance[2]. The Malmquist index is used as one of the modern methods for

measuring changes in the total factor productivity of production factors by

analyzing changes in technical efficiency and technological development over time; therefore, it has received widespread attention in economic and agricultural studies due to its ability to clarify the sources of changes in productivity and analyze the efficiency of production performance[5]. Despite the importance of the agricultural sector in Iraq, the limited use of modern technology, economic instability, and declining efficiency in the utilization of agricultural resources have led to a decline in agricultural productivity levels during the study period. This necessitates a quantitative (parametric) analysis to measure technical efficiency and technological change and to determine

Research Problem

The research problem lies in the clear fluctuations in productivity and efficiency levels in the Iraqi agricultural sector during the study period, resulting from the economic and technical challenges faced by the sector, which resulted in inefficient use of agricultural resources and a reduced contribution of the agricultural sector to the national economy. This necessitates measuring changes in the total factor productivity and analyzing technical efficiency and technical change using the Malmquist index.

Research Hypothesis

This study assumes that the Malmquist Productivity Index can effectively measure changes in total factor productivity and identify the contributions of technical efficiency change and technological change to agricultural productivity in the Iraqi agricultural sector during the period 1990–2023.

Research Objectives

their impact on the total factor productivity in the Iraqi agricultural sector[1] Despite the importance of previous studies on technical efficiency and productivity in agriculture, limited research has comprehensively examined changes in total factor productivity in the Iraqi agricultural sector over a long time period using the Malmquist Productivity Index. In addition, previous studies have not clearly distinguished the respective contributions of technical efficiency change and technological change to productivity performance during the period 1990–2023. Therefore, this study seeks to fill this research gap by providing a comprehensive analysis of total factor productivity and its components using the Malmquist Productivity Index and DEAP software.

1. Measure changes in total factor productivity in the Iraqi agricultural sector using the Malmquist index.
2. Analyze technical efficiency and technical change in the agricultural sector during the study period.
3. To analyze the contribution of technological change to changes in total factor productivity in the Iraqi agricultural sector.
4. To describe the changes in technical efficiency, technological change, and total factor productivity in the Iraqi agricultural sector during the study period (1990–2023).

Scope of the Study

Time frame: 1990–2023.

Geographical scope: The Iraqi agricultural sector.

Research Methodology:

The study was based on annual data (time series) for the Iraqi agricultural sector for

the period 1990–2023, with agricultural gross domestic product serving as the dependent variable (y), while agricultural capital and agricultural labor served as the independent variables (X_1 , X_2). The data were obtained from official reports and statistics issued by the Iraqi Ministry of Planning and the Central Bureau of Statistics[7]. The study also relied on the Malmquist Productivity Index, using the DEAP 2.1 software, to measure changes in total factor productivity and analyze the components of technical efficiency change (EFFCH) and technological change (TECHCH) during the study period. [4].

$$\Delta y_t = a + \delta y_{t-1} + BT + \sum_{i=1}^m ai \Delta y_{t-1} + \varepsilon_t$$

The study also relied on the Malmquist index, using the DEAP program, to measure changes in total factor productivity and to analyze the components of technical efficiency and technical change during the study period[4].

TFPCH = EFFCH * TECHCH

In which he notes:

TFPCH = Change in Total Factor Productivity

EFFCH = Change in Technical Efficiency

TECHCH = Technical Change

Previous studies

Numerous studies have addressed the topics of technical efficiency, technological change, and total factor productivity in the agricultural sector using methods such as econometrics analyze, data envelopment analysis, and the Malmquist index, with the aim of measuring the efficiency of agricultural resource use and analyzing the impact of technological development on agricultural performance. The study by Al-Naimi and

Zidan (2017) aimed to estimate total factor productivity, technical efficiency, and the technological gap in the agricultural sector in Syria, Turkey, and Iran using the DEAP method. The results showed variations in efficiency and productivity levels among the countries studied, with Iran outperforming the others due to technical progress and improvements in the agricultural production environment. The study emphasized the importance of developing institutions that support the agricultural sector and increasing the efficiency of resource use. Similarly, a study by Al-Tayeb et al. (2019) examined the impact of technical and technological progress on agricultural development in Arab countries during the period 2000–2017, relying on panel data models and cointegration tests. The results showed a positive effect of capital on agricultural GDP, while the effect of agricultural labor was negative due to its inefficient use and reliance on traditional methods of agricultural production, in addition to the existence of a long-term relationship among the study variables. Meanwhile, the study by Lafta and Ali (2020) aimed to measure economic efficiency, technical change, and total factor productivity in a number of Iraqi agricultural companies using Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). The results revealed disparities in efficiency levels among agricultural companies, as well as a relative improvement in total productivity resulting from technological advancements in some companies. The study recommended supporting the use of modern agricultural technologies to improve production performance. The study by Al-Abbasi (2025) analyzed the efficiency of the Libyan agricultural sector using the Data Envelopment Analysis (DEA) model and the Tobit model. The results showed clear differences in efficiency levels among agricultural regions. It also revealed that technical progress and investment in

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modern technology are among the most significant factors influencing the improvement of the agricultural sector's efficiency. The study recommended the need to develop agricultural support policies and encourage the use of modern technologies to improve agricultural production efficiency.

Section 2: Technical Efficiency, Technological Change, and Total Factor Productivity

First: The Concept of Technical Efficiency

Technical efficiency is one of the fundamental concepts in agricultural economic analysis, as it reflects a production unit's ability to achieve the maximum possible output using a given amount of available resources, or to achieve a specific level of output with the minimum possible amount of resources, thereby reflecting the efficient use of agricultural inputs and the reduction of waste in economic resources. The importance of technical efficiency in the agricultural sector is highlighted by its role in raising production levels and improving the utilization of available resources, thereby contributing to sustainable agricultural development[4].

Second: The Concept of Technological Change

Technological change refers to the evolution of agricultural production methods and techniques resulting from the use of modern technology, agricultural mechanization, advanced irrigation methods, and improved seeds, which leads to increased productivity and improved production efficiency. Technological change is one of the main factors influencing the growth of agricultural output and the increase in the total productivity of production factors, as it

helps reduce production costs and improve the quality of agricultural products[3].

Third: Total Factor Productivity

Total Factor Productivity (TFP) reflects the relationship between the size of agricultural output and the total inputs used in the production process, and are used to measure the agricultural sector's efficiency in utilizing available economic resources. An increase in total factor productivity indicates improved production performance as a result of technological advancement or improved technical efficiency, while a decrease reflects inefficient resource use or a decline in the level of technology employed[2].

Fourth: The Malmquist Index for Measuring Productivity

The Malmquist index is one of the modern methods used to measure changes in the total factor productivity of production factors and to analyze changes in technical efficiency and technological progress over time, as it relies on data envelopment analysis (DEA) to measure the productive performance of various economic units. This index is distinguished by its ability to identify the sources of changes in productivity, whether resulting from efficiency improvements or technological advancements [5]. The Malmquist index is calculated using the following formula

$$\text{TFPCH} = \text{EFFCH} * \text{TECHCH}$$

TFPCH = Change in Total Factor Productivity

EFFCH = Change in Technical Efficiency

TECHCH = Technological Change

A rise in the index value indicates an improvement in the total factor productivity, while a decline indicates a decline in efficiency and productivity levels in the agricultural sector.

Fifth: The Importance of the Malquist Index in the Agricultural Sector

The importance of the Malquist index lies in its role as an analytical tool that helps assess the performance of the agricultural sector and measure the efficiency of agricultural resource use, in addition to its role in determining the impact of technological development on the production process. It is also used to support agricultural policies and decision-making related to improving agricultural productivity and increasing the efficiency of various factors of production [2].

Third Objective: Calculating the Malquist Index for the Iraqi Agricultural Sector

First: Calculating the Malmquist Index and Analyzing the Results

The Malmquist index is one of the modern methods used to measure changes in total factor productivity and to analyze changes in technical efficiency and technological change over time; it helps identify the sources of change in agricultural productivity during the study period [8]. The Malmquist productivity index is based on measuring changes in total factor

productivity between two time periods by analyzing changes in technical efficiency and technological change. The index consists of two main components: the change in technical efficiency (EFFCH) and the technological change (TECHCH); their product represents the change in total factor productivity (TFPCH). An index value greater than one indicates an improvement or growth in productivity, while a value less than one indicates a decline in productivity; if the value is equal to one, this reflects a stable level of productivity during the study period[5].

Malquist Index Results

The study adopted the calendar years (1990–2023) as decision-making units (DMUs) in the Data Envelopment Analysis (DEA), with each year treated as an independent unit of comparison based on the agricultural input and output data used in the analysis. The DEAP software also used the years in which full efficiency was achieved as reference years to construct the efficiency frontier used in calculating the Malquist index, which served as the basis for measuring changes in technical efficiency, technical change, and total factor productivity over the study period.

Table (1) Results of the Total Factor Productivity Analysis of the Iraqi Agricultural Economy Using the Malquist Index for the Period (1990–2023)

1. yaer	EFFCH	TECHCH	PECH	SECH	TFPCH
2. 1990	1.332	0.051	1	1.332	0.068
3. 1991	0.487	0.1	0.969	0.503	0.049
4. 1992	0.792	0.145	0.953	0.831	0.114
5. 1993	1	0.194	1	1	0.194
6. 1994	0.4	0.601	1	0.4	0.24
7. 1995	1.183	0.709	1.031	1.147	0.839
8. 1996	1.165	0.664	1.05	1.11	0.774
9. 1997	1	0.715	1	1	0.715
10. 1998	0.919	0.631	1	0.919	0.58
11. 1999	1.717	0.581	1	1.717	0.998
12. 2000	1.084	0.618	1	1.084	0.67

13. 2001	1	0.704	1	1	0.704	
14. 2002	0.871	0.757	1	0.871	0.659	
15. 2003	0.628	0.739	1	0.628	0.464	
16. 2004	0.848	0.748	1	0.848	0.634	
17. 2005	1	0.804	1	1		0.804
18. 2006	0.86	0.978	0.995	0.865	0.842	
19. 2007	0.858	1	1	0.858	0.857	
20. 2008	1.1	2.342	1	1.1		2.576
21. 2009	1	2.209	1	1	2.209	
22. 2010	0.847	0.11	0.98	0.864	0.093	
23. 2011	0.862	0.67	1.02	0.845	0.578	
24. 2012	1.144	0.632	1		1.144	0.723
25. 2013	0.825	0.762	1	0.825	0.628	
26. 2014	0.949	1.5	0.999	0.95	1.423	
27. 2015	0.818	0.428	0.999	0.819	0.351	
28. 2016	0.882	0.498	1	0.882	0.439	
29. 2017	0.986	0.636	1	0.986	0.627	
30. 2018	1	0.704	1	1	0.704	
Average total	0.950241	0.732069	0.999862	0.949241	0.708828	
Duration						

Source: Prepared by the researcher based on the outputs of the DEAP program [4]

Note: Although the study data cover the period 1990–2023, the DEAP 2.1 software reports the Malmquist Productivity Index results only up to 2018, as the last five years are treated as reference years in the estimation process.

The results of the Malmquist index revealed fluctuations in the levels of technical efficiency, technical change, and total factor productivity in the Iraqi agricultural sector during the study period, as the values of the

indices varied from year to year depending on the economic and technical conditions experienced by the agricultural sector. The results also indicated that the average technical efficiency reached approximately 0.95, suggesting a relative convergence toward optimal efficiency, while the average technical change was approximately 0.73, reflecting weak technological development in the agricultural sector during the study period. The average change in total factor

productivity was 0.71, indicating a relative decline in agricultural productivity levels. The year 2008 recorded the highest value for the total factor productivity index at 2.58, as a result of improvements in technical efficiency and technical change, while the year 2010 recorded the lowest value at 0.093, due to a decline in efficiency and a regression in the level of technological development. Overall, the results indicate that weak technological

progress and instability in the efficient use of agricultural resources were among the most significant factors influencing the decline in agricultural productivity during the study period. This necessitates the development of modern agricultural technologies and improved management of agricultural resources to enhance the efficiency of the Iraqi agricultural sector and increase its productivity.

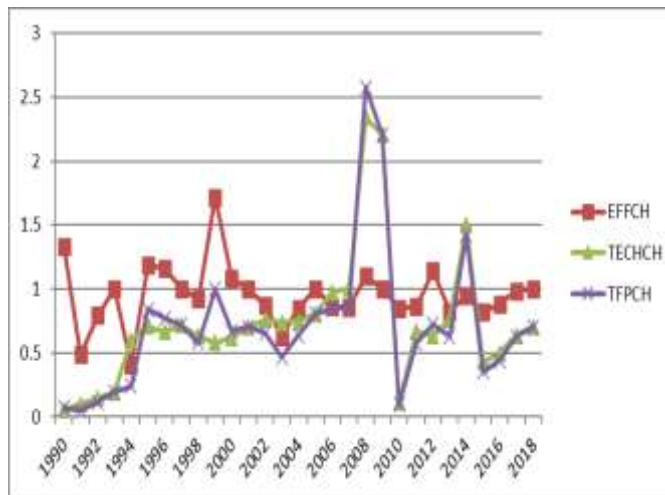


Figure (1) Total Productivity and Its Components According to the Malmquist Index (1990–2018)

Source: Compiled by the researcher without reference to Table (1)

Third: An Analysis of the Current State of Technical Efficiency and Technological Change in the Iraqi Agricultural Sector

The results of the Malmquist index indicate clear fluctuations in the levels of total factor productivity (TFP) of agricultural production factors in Iraq during the study period (1990–2023), with the average total factor productivity index (TFPCH) standing at approximately 0.708, a value less than one, indicating a general decline in total factor productivity over the study period. This is attributed to a range of challenges faced by the Iraqi agricultural sector, most notably the wars and economic sanctions of the 1990s, insufficient agricultural investment, deteriorating agricultural infrastructure, limited adoption of modern technologies, water scarcity, and climate change—all of which negatively impacted the efficient use of agricultural resources[2].

It is also evident that the highest value of the total productivity index was (2.576) in 2008, followed by (2.209) in 2009; this is attributed to the relative improvement in economic conditions and increased attention to the agricultural sector during that period. In contrast, the index recorded its lowest levels during the early years of the study period,

reaching 0.068 in 1990 and 0.049 in 1991 as a result of the difficult economic conditions that affected agricultural activity. The results show that the average change in technical efficiency (EFFCH) was 0.950, which is less than one, indicating a relative decline in the efficiency of agricultural resource use. The average technical change (TECHCH) was approximately 0.732, indicating that the decline in total productivity was more closely linked to weak technological progress in the Iraqi agricultural sector. The exceptionally low value of technological change (TECHCH = 0.051) recorded in 1990 reflects the difficult economic and institutional conditions prevailing at the beginning of the study period. The Iraqi agricultural sector was severely affected by the consequences of the Iran-Iraq war, the Gulf War, the subsequent economic sanctions, and the limited adoption of modern agricultural technologies, all of which negatively affected technological progress and agricultural productivity.. The average change in net technical efficiency (PECH) was 0.999, a value close to one, indicating relative stability in the technical management of agricultural resources during the study period.

Conclusion

1. The results of the Malmquist index showed clear fluctuations in the total factor productivity of the Iraqi agricultural sector during the study period.
2. The average technical efficiency was 0.95, indicating a relative proximity to optimal efficiency.
3. Technical change recorded a relative decline, reflecting the limited use of modern agricultural technology.

Recommendations

1. The need to support the use of modern agricultural technologies in Iraq's agricultural sector.
2. Developing agricultural infrastructure and improving the efficient use of agricultural resources.
3. Increasing agricultural investments directed toward mechanization and modern technology.

4. Technical change was found to be one of the factors contributing to the decline in agricultural productivity during the study period.

5. In some years, productivity improved as a result of higher technical efficiency and technological advancement

4. Supporting agricultural extension and training programs to improve the efficiency of workers in the agricultural sector.

5. Adopting stable agricultural policies that contribute to raising productivity and efficiency and achieving sustainable agricultural development.

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