Measurement and Determinants of Total Factor Productivity Convergence Hypothesis: A Case Study of Non-Oil Arab Countries

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Abstract:

The study aims to investigate absolute beta convergence through cross-sectional analysis, explore Comparable Total Factor Productivity (CTFP) convergence among Arab countries, and analysis the impact of economic variables on CTFP convergence. A combination of cross-sectional analysis, time series unit root tests, cointegration tests, and second-generation panel unit root tests (PURTs) is employed. The VARSEL method is utilized to identify determinants of CTFP growth. This study approved that the Cross-sectional analysis confirms absolute beta convergence. Long-term CTFP convergence and catch-up are observed in Egypt, with catch-up evident in Jordan. Stochastic Total Factor Productivity (TFP) convergence is detected through cointegration tests. Strong evidence of Stochastic CTFP convergence between Egypt and Jordan with the United States is provided via PURTs. Productivity per employment is the sole determinant of CTFP growth, while the population growth rate significantly influences Comparable Real Total Factor Productivity (RTFP) growth. The study recommends prioritizing institutional quality to enhance the positive impact of economic variables on TFP growth and convergence. It underscores the need for nuanced approaches to boost productivity in non-oil Arab countries, considering the limited influence of foreign direct investment inflows.

Keywords: Total factor productivity; Cointegration test; Institutional quality; Non-oil Arab countries

1. Introduction

Most emerging nations, particularly those with strong ties to one another politically, socially, or geographically, aspire to create an economic bloc that will benefit all parties involved in full economic integration (Abdullah & Chowdhury, 2020). Among these are the Arab non-petroleum countries. However, for these nations to meet the living standards of developed nations or even the oil-producing Arab nations, they must attain high and sustainable growth rates, considered one of the prerequisites for accomplishing this goal (Massalha, 2022).

Convergence in total factor productivity (TFP) is one of the most significant markers of growth rate convergence and subsequent catch-up. Aside from the debate between the neoclassical, who have endogenous growth models like Romer (1986) and Lucas (1988), and the neoclassical, who have exogenous growth models like Solow (1956) and Swan (1956), all agree that the only way to boost economic growth and ensure long-term sustainability is to raise total factor productivity (TFP) (Lucas

Jr, 1988; Romer, 1986; Solow, 1956; Swan, 1956). The main drivers of this increase are advancements in technology, R&D, and innovations. These factors make up for the low productivity of traditional production factors, such as labour and capital, because their productivity is eventually subject to the law of diminishing returns (Barro & Sala-i-Martin, 1990).

Total factor productivity (TFP), which we shall refer to as "productivity" or "TFP," was initially developed by Solow in 1956. The formula used to determine TFP is called the "Solow Residuals" equation (Solow, 1956). This formula calculates the long-term effects of changes in knowledge and technological advancement of the labour force. When weighted by the percentage of each capital's contribution to the output, this formula calculates the difference between the growth rates of production and physical and human capital. This discrepancy is due to technological advancement. TFP can more accurately represent the conditions of economic growth in any nation because of its precise definition, which states that the proportion of output increase cannot be explained by the accumulation of traditional production inputs (Feenstra et al., 2015).

The concept of the phenomenon of productivity convergence (TFP) between nations was also introduced to the Solow model. This model states that only technological advancement can produce a sustainable higher marginal return in developing or emerging nations that rely on a limited capital balance (decreasing marginal productivity over time), allowing them to catch up to developed countries and converge.

Romer (1986) and Lucas (1988) accepted the idea of conditional convergence as a result of the dissemination and transfer of technology and knowledge between leading countries to dependent countries as a result of trade liberalisation, international investments, the increase in the rate of saving, investment, population growth, and research and development activities leading to the development of production technologies, even though they denied the idea of absolute convergence of mean per capita income as an indicator of TFP convergence based on the law of increasing marginal product of knowledge and that increasing returns and the technological level make the per capita income in developed countries takes different and divergent paths from per capita income in developing countries (Lucas Jr, 1988; Romer, 1986).

TFP convergence has been defined in several ways, including the definitions given by Barro (1991), Boumol (1986), and Barro and Sala-i-Martin (1992). According to these definitions, TFP convergence is the process by which emerging economies grow more quickly than the world's most developed nations and catch up to them in terms of labour productivity or mean per capita income (Barro, 1991; Barro et al., 1991; Baumol, 1986). The "catch-up" theory, which holds that low-productivity nations can catch up to higher-productivity nations by growing quicker, is related to the productivity convergence hypothesis (TFP).

According to the earlier definitions, the phenomenon of TFP convergence is implicitly seen as the "penalty of being the leader" from the perspective of developed nations. It also represents the idea of "relative backwardness" with subsequent economic growth, while from the standpoint of developing nations, it represents the "advantage of being poor."

For several reasons, examining the TFP convergence and catch-up theory and its influencing factors is vital for developing or emerging nations.

First, One of the key factors influencing sustainable growth is the rise in TFP. For instance, research by Eichengreen et al. (2012) discovered that, on average, the TFP growth rate fall accounted for almost 85% of China's economic slowdown (Eichengreen et al., 2012). Furthermore, according to a study by Klenow and Rodriguez (1997), variations in productivity account for 90% of the variations in mean per capita income (Klenow & Rodriguez-Clare, 1997).

Second, a rise in TFP is one way to raise a nation's standard of living by boosting real purchasing power, closing income gaps, and helping to close the labour productivity gap between developing and developed countries. All of these factors work together to reduce absolute and relative poverty.

Third, The potential for technology transfer from developed to developing nations is shown by the TFP convergence test, and this transfer of technology is essential to preserving the momentum of economic expansion. Subsequently, the test aids in identifying the variables that may facilitate the transfer of technology from developed to underdeveloped nations.

Fourth: A "club convergence" process may cause a collection of nations with similar (economic, political, or geographic) qualities to experience an increasing convergence in their living standards and productivity levels.

The study by Loko and Diouf (2009) categorized the elements that impact productivity and their convergence into three distinct groupings (Loko & Diouf, 2009). First are macroeconomic variables: some have favorable effects like trade openness and foreign capital inflows, while others have negative effects like the inflation rate and tax distortions. The output structure (agricultural, industrial, or service) is also included in this group. The second is human capital, which provides for worker productivity, work skill, and quality of work. Institutional quality-related factors are included in the third group.

Despite the large body of research on the convergence of TFP, most of it tested the hypothesis indirectly by estimating productivity as the residual of a production function (Imrohoroğlu & Üngör, 2016), including its conditions and limitations or by using the Real GDP index, the growth index, or the mean real GDP per capita index as an indicator of the balance of technology and knowledge. Even with the research volume, none have focused exclusively on Arab nations. Previous research believed that some criteria identified productivity and investigated their influence. Therefore, they arbitrarily selected the drivers of productivity and their convergence (Inklaar & Woltjer, 2021).

This study aims to contribute to the literature on productivity convergence and its determinants in three significant ways. Firstly, it addresses the challenges associated with measuring productivity, particularly Total Factor Productivity (TFP), by employing a novel approach based on the total productivity index. This method involves modifications in the calculation process, accommodating variations in the capital depreciation rate over time and considering disparities in capital goods, with data from the Penn World Tables 10.01. Secondly, the study examines the convergence hypothesis within non-oil Arab countries through a comprehensive analysis utilizing cross-sectional, time series, and panel data techniques, augmented by the application of Second-generation panel unit root tests. Lastly, the research evaluates the impact of eight potential variables identified in prior studies as influential factors affecting productivity convergence. It applies a Variable Selection method to ascertain the most suitable explanatory variables for estimation within the context of non-oil Arab countries. Through these approaches, this study seeks to enhance understanding and provide valuable insights into productivity dynamics and determinants, particularly within the specified regional context.

2. Literature Review

2.1. Productivity Convergence Hypothesis

Firstly, macroeconomic theory identifies several factors or mechanisms that can, in theory, produce convergence or divergence in levels of per capita income or productivity across countries or regions. Still, it has yet to specifically predict whether these trends will occur. We can categorize growth models into two families based on their capacity to forecast the convergence hypothesis, which will be divided into two groups, notwithstanding the potential for oversimplification:

The first group decided that the "advantage of being poor" or the "penalty of being the leader" would lead to the convergence hypothesis being realized. As a result, poor countries would grow faster than developed countries, although these models assume the stability of other factors.

The second group concluded that the convergence hypothesis would not hold true because developed nations consistently record faster growth rates than developing nations, there are significant output differences between the two groups, and the difference in income and productivity levels between them is infinite.

According to seminal works such as Solow (1956), the factors contributing to convergence encompass several key principles (Solow, 1956). Firstly, the law of diminishing returns elucidates that economies with lower initial capital levels, characteristic of developing countries where capital is scarce, tend to exhibit higher returns on investment than those with abundant capital, typically found in developed nations. Additionally, the capacity of developing countries to emulate existing technologies at a substantially lower cost than the expense of innovating new technologies underscores another factor facilitating convergence. Furthermore, the mobility of production factors and the proliferation of international technical exchange foster convergence dynamics by promoting the dissemination and adoption of advanced technologies across economies. These fundamental principles, as outlined by Solow (1956) and corroborated by subsequent research, provide a theoretical framework for understanding the global productivity convergence mechanisms.

Research by Romer (1986) and others in the second group identified certain factors as impediments to achieving convergence (Romer, 1986). Firstly, the Law of Increasing Returns challenges the notion of convergence by suggesting that in developed countries, expanding physical capital augmented by human capital and knowledge does not lead to diminishing returns in the long run, thus potentially perpetuating disparities. Secondly, the unequal distribution of natural resources is highlighted as a hindrance to convergence, as regions endowed with abundant resources may only sometimes converge due to variations in resource endowments. Additionally, the unequal distribution of resources can exacerbate disparities rather than foster convergence. Moreover, international exchange may not necessarily result in the efficient flow of production factors, particularly as developing countries may remain entrenched in relatively obsolete technologies, impeding their ability to converge with technologically advanced economies.

Islam's survey study (2003) introduces a nuanced classification of convergence phenomena based on three distinct criteria (Islam, 2003). Firstly, the geographical criterion distinguishes between convergence occurring within a single economy and convergence observed among groups of economies, thereby highlighting the difference between intra-national and inter-national convergence dynamics. Moreover, it delineates between global convergence, spanning across economies worldwide, and local convergence, characterised by convergence within specific clusters or groups of economies, often referred to as "club convergence." Secondly, the variable criterion discerns between convergence of growth rates and convergence of income levels and between convergence of mean per capita income and convergence of Total Factor Productivity (TFP), providing a comprehensive framework to understand different facets of convergence. Lastly, the classification considers the data standard and measurement methods, contrasting beta convergence and sigma convergence for cross-sectional data analysis, and distinguishing between deterministic and stochastic convergence methodologies for time series analysis.

Global convergence happens when nations come together, local convergence happens when nations come together, and club convergence happens when nations come together under conditions that are similar in the beginning. As a result, convergence in the sense used in earlier notions might be either absolute or conditional.

Convergence research utilises various methodologies, including informal and formal cross-section approaches, time-series analysis, panel studies, and distribution analysis, to investigate the phenomenon comprehensively.

For example, absolute (unconditional) beta convergence, the tendency for poorer countries to expand faster than affluent countries, occurs between groupings of countries. According to the **β** convergence hypothesis, countries with lower initial real income or TFP expand more quickly than those with higher initial real income or TFP.

Conditional beta convergence happens when characteristics like population, institutional factors, human capital balance, and degree of openness cause poorer countries to grow more quickly than affluent ones. Poorer countries will not grow quicker than wealthier countries if the conditions are unmet. The purpose of sigma-convergence, or "the convergence hypothesis is met," is to determine whether the productivity index's dispersion, as determined by the standard deviation, diminishes over time.

In beta or sigma convergence testing, the informal or formal cross-section approach is frequently utilised, along with the time series and panel data approach to some extent. The particular convergence test, random convergence test, local convergence test, and TFP convergence test all make extensive use of panel data, the formal cross-section technique, and the time series approach.

A relatively new method based on time series analysis and panel data is the idea of stochastic convergence and particular convergence. When a region's total productivity (TFP) is comparable to the other areas, convergence occurs. Reducing disparities in TFP over an extended duration between nations or regions is another aspect of "catching up" operations; this can go on forever. Unit root and co-integration tests for data, whether time series or panel data are two of the measuring techniques used within the framework of the idea of random or specific convergence. Khan (2012) identified four notions of convergence in his study.

In the realm of time series analysis, convergence can manifest in two distinct forms. Firstly, random convergence and catching up occur when a country's productivity series relative to the regional mean (difference series) exhibits directional stationarity, indicating a convergence trend. Conversely, convergence defined in the long run is achieved when the relative productivity series demonstrates a stationary mean, signifying convergence without a specific direction. In the context of panel data analysis encompassing cross-sectional units and time series, convergence is further delineated. Absolute random convergence occurs when unit root tests for panel data series confirm stationarity in the absence of individual fixed effects for the countries within the group. On the other hand, conditional random convergence is evidenced by unit root tests indicating stationarity for select countries amidst the presence of individual fixed cross-sectional effects. These distinctions offer valuable insights into the multifaceted nature of convergence phenomena across different analytical frameworks.

The phenomenon of random convergence in per capita output supported their theory of random directions in the income series. This idea states that the GDP per capita log-direction unit-roots of two nations show the existence of a shared random direction.

Therefore, the divergence between the two random direction series is guaranteed to be in the stationary case produced by absolute convergence.

Recent studies examining local convergence and club convergence among groups of countries have provided nuanced insights into productivity dynamics within specific regional contexts. Safdar & Nawaz (2020) investigated Total Factor Productivity (TFP) convergence across six South Asian Association for Regional Cooperation (SAARC) countries over the period 1972-2012. Employing cross-sectional data analysis with the OLS method, they tested for beta and sigma convergence, while employing the Levin, Lin and Chu (LLC) test and Hadri test for time series analysis to assess absolute and conditional productivity convergence. Their findings did not support the hypotheses of TFP convergence, neither beta nor sigma nor did they find evidence for absolute or conditional TFP convergence (Safdar & Nawaz, 2020). Rath (2019) focused on the ASEAN-5 countries from 1968 to 2014, utilising the Phillips–Sul test to analyse unit root presence with breaking points. Their study concluded the presence of club convergence in productivity among the sample countries without employing a developed country as a reference (Rath, 2019). Nwosu et al. (2013) examined absolute and conditional TFP convergence across 23 African countries from 1960 to 2003, employing the LLC and Im, Pesaran and Shin (IPS) tests for panel data unit root analysis. Their results indicated evidence of conditional convergence and the emergence of club convergence for TFP among the sample countries, albeit with weak evidence of absolute convergence, contrasting with findings from advanced economies. These studies collectively contribute to understanding convergence dynamics within specific regional groupings, highlighting the complexities and variations inherent in productivity convergence across different contexts (Nwosu et al., 2013).

2.2. Determinants of Productivity Convergence

Theoretically, the variables and constants of the Solow remainder—the growth of real output, the balance of human and physical capital, and the percentage of each that goes towards the formation of the production—identify TFP and its growth, and then the possibility of its convergence or divergence between countries. As a result, all of the variables and causes that influence the Solo residuals' components indirectly impact productivity; there are numerous such factors and variables.

The research conducted by Loko and Diouf (2009) offers an extensive analysis of the variables that determine the productivity of production factors and elucidates the causes of productivity divergence or convergence (Loko & Diouf, 2009). The variables that affect TFP were categorised into three groups in this study; the first category includes macroeconomic variables that either promote or impede productivity growth, such as the rate of inflation, which is thought to be a sign of economic instability; large government sizes; and taxes, which cause market inefficiencies and impede productivity growth.

Conversely, increased capital mobility, trade openness and liberalisation are anticipated to boost productivity growth. International trade serves as a conduit for the transfer of technology between nations because it fosters competition, which breeds innovation. Therefore, nations with greater trade openness are anticipated to see a faster productivity rise. The same reasoning holds true for capital inflows, as FDI inflows are associated with knowledge transfer and technological diffusion, which foster productivity increases. Because non-agricultural economies expand their productivity quicker than agricultural ones, the structure of output—whether manufacturing-, service-, or agriculture-intensive—also affects productivity growth.

The factors that measure worker productivity, work skill, quality of work (human capital), and physical capital are included in the second group. The justification is that job skills positively impact productivity. The third group identifies productivity and income growth mostly based on institutional quality. The reasoning behind this is that institutions protect property rights, encourage innovation, and soften the rigidity of labour markets. As a result, they are crucial in fostering technological advancement and raising the general allocative efficiency of production factors.

Eight variables—the human capital index, the internal rate of return on the capital balance, the mean worker's share of output, the rate of population growth, the percentage of foreign direct investment, the degree of trade openness, the inflation rate, and the exchange rate—are known to be measurable and are likely to have an impact on convergence. These variables fall into the first and second groups. Previous research has shown that these variables are also highly significant.

The convergence theory is predicated on three key tenets in every scenario: perfect competition, technological advancement, and the absence of external economies. Any assumption that is broken results in divergence as there is little proof of convergence.

The growth and convergence research has examined the effects of some of these determinants at the applied level, particularly foreign direct investment (FDI) and trade liberalization or trade openness (TO). Numerous investigations have examined the impact of TO on TFP convergence, with varying degrees of success. Melitz's (2003) study claims that trade liberalization increases the level of competition among businesses, which propels the growth of more productive firms at the expense of less productive businesses (Melitz, 2003). Similarly, numerous other studies have seen the degree of international openness as a critical market for disseminating technological advancement, raising total output.

However, some contend that although TO and productivity growth (TFP) have a positive and statistically significant association, its role in the catch-up process is still debatable because it causes convergence to occur extremely slowly (Edwards, 1998). Specialization through trade was not significant in bridging the productivity gap (Stehrer & Woerz, 2009).

The study conducted by Loto & Ojapinwa (2014) on Nigeria concluded that FDI positively impacts productivity and growth. It has also been acknowledged that capital inflows in the form of foreign direct investment (FDI), both inward and outward, represent important channels for technology transfer, improving workers' managerial and technical skills, increasing job opportunities, improving the balance of payments, and increasing competition. These factors help in the rapid convergence of productivity (TFP) between Emerging and developed countries (Loto & Ojapinwa, 2014). According to the findings of Akinlo & Adejumo's (2016) study on Nigeria, foreign direct investment (FDI) is the primary factor impacting productivity (Akinlo & Adejumo, 2016).

However, other research has demonstrated that, as in Pakistan, FDI has no discernible impact on productivity(Falki, 2009). Instead, FDI may harm productivity, as seen in the example of

Turkey and the BRIC nations gaining convergence (Filiz, 2014). Malikane and Chitmabara's (2017) research on African nations also demonstrated the link (Malikane & Chitambara, 2017). Nonetheless, research by Bijsterbosch and Kolasa (2010) on nations in Central and Eastern Europe confirms that the host nation's ability to absorb new investment and the availability of human capital have a significant impact on the expected returns from growing FDI inflows (Bijsterbosch & Kolasa, 2010). According to Tintin's (2012) study, the extent of foreign direct investment (FDI) impact on total factor productivity (TFP) is contingent upon the size of capital intensity. The convergence hypothesis will be realized if FDI is accompanied by heightened R&D endeavours (Tintin, 2012).

Recent studies examining the determinants of Total Factor Productivity (TFP) convergence offer valuable insights into the factors influencing productivity dynamics across various contexts. Ahmad (2023) investigated productivity determinants in Pakistan from 1982 to 2020, employing the Lasso method to select variables affecting TFP growth. Their findings revealed significant negative long-run impacts of spending on education, inflation, unemployment rate, and local patents on productivity, while imports of devices, machinery, and patents for foreigners positively influenced TFP growth (Ahmad 2023). Adnan et al. (2020) focused on Pakistan's productivity determinants from 1970 to 2018, utilizing the ARDL approach and Granger causality test, highlighting the long-run relationships between TFP, foreign direct investment, and human capital (Adnan et al., 2020). Asongu et al. (2020) explored the simultaneous openness hypothesis across 25 sub-Saharan African countries from 1980 to 2014, finding that trade openness positively influenced productivity growth (Asongu et al., 2020). Adnan et al. (2019) examined TFP determinants in four South Asian countries, revealing positive effects of foreign direct investment and trade openness on TFP growth from 1975 to 2016 (Adnan et al., 2019). Tebaldi (2016) analyzed 63 countries from 1960 to 2011, identifying club convergence while rejecting global TFP convergence. They attributed TFP convergence primarily to institutional quality and openness, shedding light on the nuanced interplay of factors shaping global productivity dynamics (Aghion et al., 2009; Tebaldi, 2016).

3. The Study Problem

The study problem can be delineated into several key points. Firstly, while a substantial body of economic literature addresses productivity convergence and catch-up hypotheses, prior studies predominantly relied on cross-sectional or panel data for countries grouped by income levels or regions. However, there has been a noticeable dearth of research focusing on specific regional blocs, industries, or sectors within countries, particularly within the Arab region, where club-convergence dynamics may be at play.

Secondly, previous studies often indirectly tested Total Factor Productivity (TFP) convergence using indicators such as real GDP indices, which may not fully capture productivity dynamics.

Moreover, direct tests of TFP convergence often faced methodological challenges related to estimating production functions. Nevertheless, recent updates to the Penn World Table (PWT) have introduced indicators like Comparable Total Factor Productivity (CTFP) and Real Total Factor Productivity (RTFP), offering improved tools for international comparisons and TFP analysis.

Thirdly, previous studies on the determinants of productivity convergence often need to consider the complex interplay of variables influencing productivity before selecting factors. Therefore, the study aims to address these gaps by examining the convergence of TFP among non-oil Arab countries compared to the United States, utilizing updated productivity indicators and systematically investigating the determinants of productivity convergence. The study seeks to answer two central questions: whether TFP convergence among non-oil Arab countries towards US productivity levels will occur in the long run, and what factors contribute to this convergence process.

4. Scope of the Study

The scope of this study is delimited to examine the convergence of productivity among non-oil Arab countries, specifically focusing on Egypt, Tunisia, Morocco, and Jordan. Excluded from the analysis are the oil-rich Arab nations, namely the Gulf Cooperation Council countries (Saudi Arabia, Oman, the United Arab Emirates, Kuwait, Qatar, and Bahrain), Iraq, Libya, and Algeria. This exclusion is justified due to the presence of extreme values in the data pertaining to productivity indices and their determinants, largely attributed to the heavy reliance on oil production in these countries and the ensuing impact of oil rent on productivity.

Analysis of available data revealed significant limitations for other non-oil Arab nations such as Lebanon, Syria, Yemen, Mauritania, Somalia, and Djibouti, where data on productivity were unavailable, and other variables exhibited extreme fluctuations, notably in the case of Sudan. Therefore, the study concentrates on the aforementioned four countries situated within the Arab world, characterised by their non-dependence on oil rents for economic growth or productivity. Furthermore, these countries offer a sufficient number of annual observations for all variables under consideration throughout the period spanning from 1976 to 2019, facilitating a comprehensive analysis of productivity convergence and its determinants.

5. Objective

This study aims to investigate three key objectives pertaining to the total factor productivity (TFP) convergence among Egypt, Tunisia, Morocco, and Jordan, in comparison to developed countries such as the United States. The objectives are outlined as follows: Test the convergence hypothesis of productivity (TFP) between the emerging countries of Egypt, Tunisia, Morocco, and Jordan, as well as the developed nation, the United States. Examine the convergence hypothesis of (TFP) within the Egypt, Tunisia, Morocco, and Jordan groups. Assess the impact of significant economic variables on the convergence or divergence of TFP in the four countries above, utilising available time series data spanning from 1976 to 2019.

6. Methodology

The methodology employed in this study comprises two main approaches: a descriptive analysis to elucidate the theoretical framework and a quantitative analysis to test the proposed hypotheses. The following steps were undertaken:

6.1. Descriptive Analysis:

Initially, a descriptive approach was utilised to present and analyse the theoretical underpinnings of the study subject, providing a comprehensive overview of the concepts and theories relevant to productivity convergence.

6.2. Quantitative Analysis:

Subsequently, a quantitative approach was adopted to test the hypotheses regarding productivity convergence. This involved employing cross-sectional data analysis, treating the sample countries as individual entities, and utilising both time series and panel data techniques.

Time series data analysis was conducted to assess the convergence hypothesis of TFP among Egypt, Tunisia, Morocco, Jordan, and the United States over the specified period.

Panel data techniques were employed to investigate the convergence hypothesis further, utilising second-generation panel unit root tests for panel data analysis. This approach allows for a robust examination of TFP convergence considering both cross-sectional and time series dimensions.

6.3. Determinants of Convergence:

Variable selection and stepwise least squares methodology were applied to understand the determinants of TFP convergence. This method facilitated the selection of explanatory variables conducive to estimation, out of a pool of eight potential variables identified from previous studies.

7. An Overview of the Most Important Indicators of the Sample Countries

By 1974, the Arab countries experienced significant shifts in their social and economic landscapes, largely attributed to the surge in oil prices and the adoption of open-door policies akin to those of advanced industrial nations, exemplified by Egypt. Fast forward to 2019, these nations have been fervently endeavouring to bolster their economies, striving to elevate their levels of economic development and enhance productivity. Table 1 presents a comprehensive overview of key demographic and economic indicators, encapsulating the multifaceted facets of this ongoing pursuit. This concerted effort underscores a collective aspiration within the Arab world to navigate towards sustainable growth and prosperity, reflecting a nuanced evolution from historical contexts to contemporary imperatives, as shown in Table 1.

Table 1: Selected indicators for the sample countries in 2019

Index	Egypt	Tunisia	Morocco	Jordan
Area (1000 km2)	995.5	155.4	446.3	88.8
Population in millions 2022	112.72	12.46	37.84	11.34
Population growth%	1.56	0.83	1.02	0.45
Real output US$ billion*	398.1	49.3	123.7	41.8
Output growth%	5.6	1.6	2.9	1.8
Mean per capita US*$	3769.0	4094.9	3355.6	3909.3
Mean growth per capita%	3.7	0.6	1.8	(0.5)
Exports, US$ billion	78.01	23.63	54.02	21.87
Imports, US$ billion	104.3	22.3	53.0	22.7
Inflation rate CPI%	9.2	6.7	0.3	0.8
Degree of openness%	41.1	102.3	76.0	85.8
FDI to GDP ratio%	2.8	1.9	1.3	1.6
External debt US$ billion	114.5	39.4	55.0	33.5

Source: World Development Indicators * At 2015 prices, ( ) is negative

From Table 1 depicting data from 2019 for the study sample, several notable observations emerge regarding specific Arab countries. Egypt stands out as the largest Arab country across various metrics including area, population, real output, output growth rates, mean per capita income growth, and population growth rate. However, it also records the highest level of consumer inflation and holds the largest foreign debt among Arab countries. Tunisia, on the other hand, leads in mean per capita income and openness among Arab nations but ranks second lowest in terms of the value of exports and imports. Morocco is the second smallest Arab country in terms of area, output, population growth, inflation rate, foreign debt balance, and output growth rate. Meanwhile, Jordan exhibits comparatively lower levels of real output, exports, imports, and population growth but ranks second highest in GDP growth among Arab countries. These insights gleaned from the data underscore the diverse economic profiles and challenges faced by different Arab nations, providing valuable context for further analysis and comparison within the study sample.

8. Methodology and Econometric Specification

8.1. Study Data and Its Sources

The study employs various indicators to analyse productivity and economic factors. Total productivity is measured through the Comparable Total Factor Productivity (CTFP) and Real Total Factor Productivity (RTFP) indices, representing total factor productivity under current purchasing power parity and constant national prices respectively. Relative total factor productivity growth (CTFPG and RTFPGit) reflects annual changes in productivity indices. The Human Capital Index (HC) assesses human capital based on schooling years and education returns, while the Real Internal Rate of Return (IRR) signifies the cost of capital. Market Exchange Rate (LnXR) denotes local currency units per dollar, and the Mean Worker's Share of Output (LnGDP/EM) represents output per worker in US dollars. Population growth rate (POPG) is calculated as the logarithm of annual population change. These data, along with Foreign Direct Investment Ratio (FDI/GDP), Trade Openness (OT), and Inflation Rate (INF), are sourced from Penn World Table (PWT 10.01) and World Bank databases. FDI, OT, and INF data are accessed from World

Development Indicators. These indicators collectively provide insights into productivity dynamics and economic factors essential for the study's analysis and interpretation.

8.2. Verifying the validity of the two productivity indicators

The difference between the comparative productivity index (CTFP) and the real productivity index (RTFP) must be stated in order to confirm the validity of the two productivity indicators provided by the Penn World Table (PWT 10.01) to test the hypothesis of convergence of productivity (TFP). The PWT tables state that the comparative real output (CGDPo) from the angle of production—which considers the prices of final goods, imports, and exports—determines the indicator CTFP. Since it is used to express each nation's annual production capacity, the Indicator CTFP reflects relative productivity as well as relative technology. The published figures are attributed to US productivity, implying that prices remain constant throughout all nations each year.

The primary flaw in the real productivity index (RTFP) is that it represents real output (RGDPNA) at local fixed prices derived from national accounts. However, because local prices are fixed for every country during the time period and a base year is chosen for every country, it is used to track productivity development over time.

As depicted in Table 2, which delineates the descriptive statistics of total factor productivity (TFP) among the sampled countries spanning the period from 1974 to 2019, with 2017 serving as the base year (set at 1), discernible trends emerge. Notably, the

United States exhibits the lowest values across the descriptive statistics for real productivity (RTFP), be it the mean, median, or extremes. Conversely, Jordan and Egypt emerge as frontrunners, boasting the highest values across all descriptive statistics pertaining to the RTFP variable. This pattern underscores a notable variance in productivity dynamics among the sampled nations, reflecting divergent trajectories in their respective economic landscapes over the specified timeframe.

Table 2: Descriptive statistics of the real total factor productivity RTFP (1974-2019)

Country	Mean	Median	The greatest value	The least value	The standard deviation
United State	0.889783	0.876213	1.016796	0.777433	0.07763
Egypt	1.257555	1.234128	1.630327	0.981091	0.211805
Tunisia	0.987209	0.982387	1.069173	0.898667	0.048729
Morocco	0.952591	0.949001	1.176196	0.814668	0.084641
Jordan	1.330906	1.167133	2.142447	0.963343	0.359029

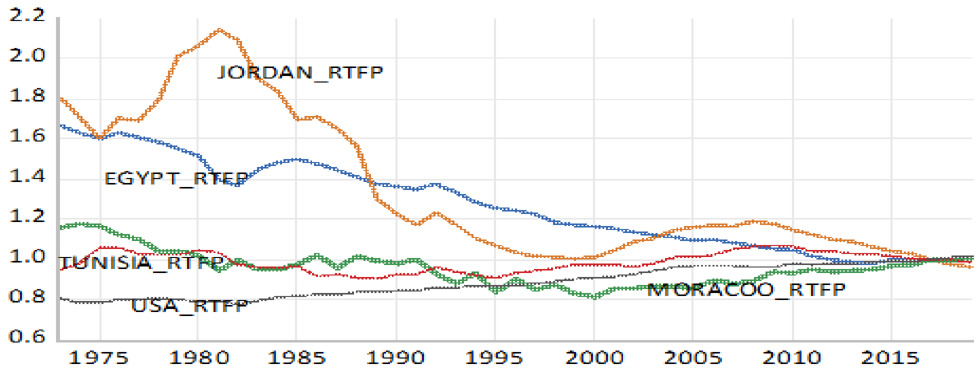
Source: Compiled by the author.

Table 2 presents findings that appear puzzling, particularly in relation to the United States, except for the standard deviation. This discrepancy has sparked considerable debate and has been examined in various studies, such as the research conducted by Imrohorogluy and Ungor (2016) investigating Real Total Factor Productivity (RTFP) in Zimbabwe and oil-exporting Gulf countries, and the study conducted by Inklaar and Woltjer (2021) focusing on Egypt. However, these studies typically attribute the observed decline in the United States' productivity index, despite its status as a developed country, to methodological issues in measuring RTFP.

Specifically, they highlight the practice of estimating production functions for all countries worldwide, assuming a uniform labour contribution rate of 2/3, without distinguishing between developed and developing nations. This methodology overlooks disparities in factors such as the number of workers, investment rates, and savings rates, which tend to be lower in developing countries. Consequently, this oversimplification may artificially inflate productivity indicators in developing countries, a factor that needs to be addressed within the scope of this study.

Depicting the trajectory of the RTFP productivity index for the sampled Arab countries alongside the United States, a noteworthy observation arises regarding the implications of data sourcing, particularly about the Penn World Table (PWT 9.01). It becomes apparent that complete convergence in RTFP would have occurred in 2015, assuming the data were derived from the previous iteration of the PWT, where 2015 served as the base year. Consequently, the utility of the productivity index (RTFP) for testing hypotheses concerning the convergence of productivity across the sampled countries is compromised, given its dependence on the determination of the base year. However, despite this limitation, RTFP remains a valuable metric for assessing the determinants of productivity, as it encapsulates localised variables pertinent to each individual country's economic context. This delineates the nuanced interplay between data methodologies and analytical frameworks in elucidating productivity dynamics within diverse national contexts, as illustrated in Figure 1.

Figure 1: Development of the RTFP productivity index for the sample of Arab countries and the United States



Source: Compiled by the author.

Since 2015 was the base year in this edition of the Penn World Table (PWT 9.01), complete convergence would have happened if the RTFP data had been signed. Because its convergence depends on identifying the base year, the productivity index (RTFP) is therefore not appropriate for testing the hypothesis of productivity convergence across the sample of countries. However, because it captures the local variables unique to each country, the RTFP will be used to measure the determinants of productivity.

The descriptive statistics for the Total Factor Productivity (TFP) index among the sampled countries spanning 1974 to 2019, with the United States serving as the base country (USA = 1), discernible trends emerge regarding the variability and central tendencies of the CTFP variable. Egypt has the highest mean value for the CTFP variable, indicating relatively robust productivity levels over the specified timeframe. In contrast, Jordan and Morocco exhibit the lowest mean values, suggesting comparatively subdued productivity performance. Moreover, Morocco has the highest standard deviation among the sampled countries, underscoring pronounced variability in TFP dynamics within its economic landscape. This pattern of disparity in TFP metrics among the sampled nations accentuates the diverse trajectories and underlying determinants shaping productivity outcomes across the Arab region, shedding light on the multifaceted nature of economic development within this context, as demonstrated in Table 3.

Table 3: Descriptive statistics of Total Factor Productivity (TFP) relative to CTFP (1974-2019)

Country	Mean	Median	The greatest value	The least value	The standard deviation
Egypt	1.164461	1.12744	1.658605	0.9116	0.174555
Tunisia	0.847713	0.782449	1.151274	0.632186	0.165108
Morocco	0.757259	0.603687	1.272365	0.522434	0.238956
Jordan	0.750719	0.804397	1.067439	0.464119	0.178532

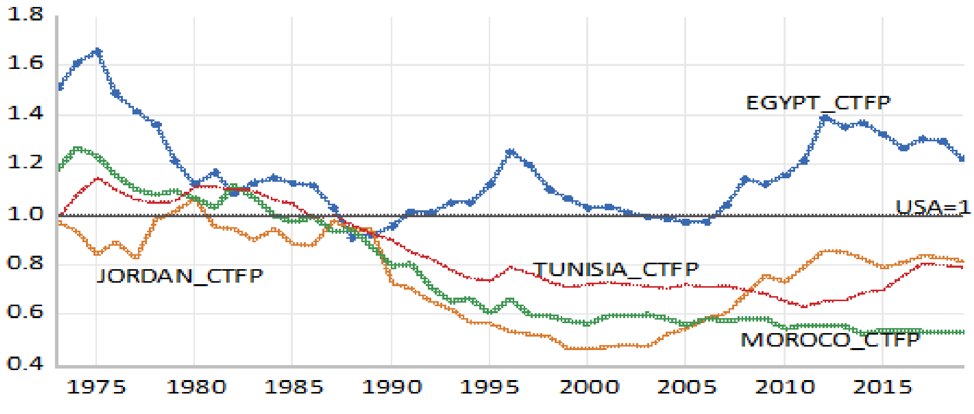
Source: Compiled by the author.

The United States is included in The comparison or relative CTFP between the sample nations, which is used to visually show the convergence or divergence of productivity as measured by Total Factor Productivity (TFP). The horizontal line representing the Country base, USA = 1, represents the United States.

A discernible pattern emerges, revealing the comparative Total Factor Productivity (CTFP) dynamics among countries over time.

Notably, from 1975 to 1989, a period characterised by convergence is observed, indicating a trend towards harmonisation in CTFP productivity levels among the sampled nations. However, a notable divergence occurs from 1990 onwards, signifying a departure from this convergence trajectory. This delineation of convergence and subsequent divergence underscores the utility of the comparative productivity index (CTFP) as a tool for testing hypotheses related to convergence and catch-up dynamics among nations. The observed pattern highlights the nuanced interplay of factors influencing productivity outcomes, illuminating shifts in comparative productivity dynamics within the sampled countries over the specified period, as depicted in Figure 2.

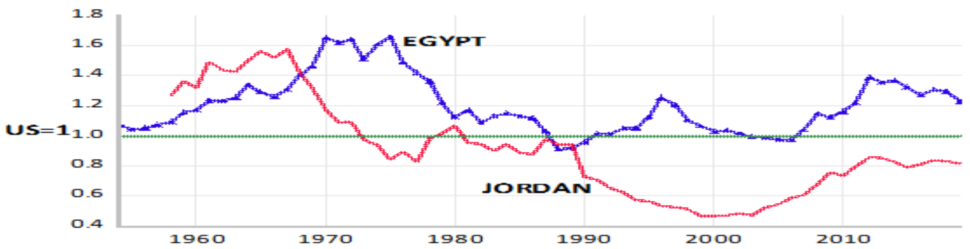
Figure 2: Development of the CTFP productivity index for the sampled Arab countries and the United States



Source: Compiled by the author.

Figure 3 illustrates an intricate analysis of total factor productivity (TFP) divergence or convergence among pairs of countries within the study sample, juxtaposed against the leading country or frontier country, the United States, is presented. The horizontal line representing the base country, with USA = 1, is a reference point for comparison. Notably, a discernible trend of convergence in comparative TFP productivity was observed between Egypt, Jordan, and the United States until 1989. However, a significant divergence emerged after that, commencing in 1990 and continuing onwards. This delineation underscores the nuanced dynamics of TFP convergence and divergence within specific country pairings over time, shedding light on the complex interplay of factors shaping productivity outcomes. Such insights from Figure 3 highlight the importance of comparative analysis in understanding the differential trajectories of productivity growth among nations, offering valuable implications for policy formulation and economic development strategies.

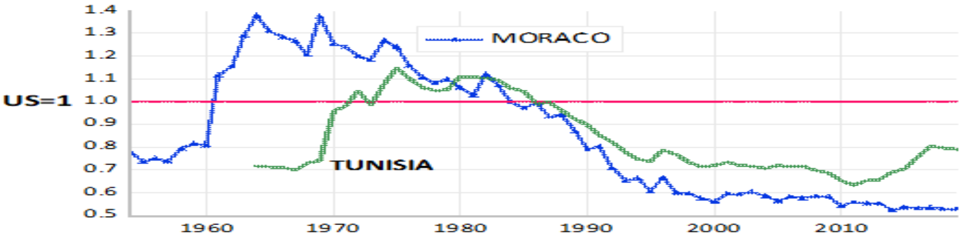
Figure 3: Convergence and divergence of CTFP productivity between Egypt - Jordan - United States.



Source: Compiled by the author.

As depicted in Figure 4, a similar trend of convergence followed by divergence in the comparative Total Factor Productivity (CTFP) indicator is discernible between Tunisia and Jordan, compared to the United States, serving as the benchmark with USA = 1. Until 1989, a notable convergence in CTFP productivity was observed between Tunisia, Jordan, and the United States, indicating a trend towards alignment in productivity levels. However, beginning from 1990 onwards, a distinct divergence emerges, highlighting a departure from the previous convergence trajectory. This pattern underscores the dynamic nature of productivity dynamics among specific country pairings over time, reflecting the intricate interplay of economic, institutional, and technological factors influencing productivity outcomes. Insights gleaned from Figure 4 contribute to a nuanced understanding of the differential trajectories of productivity growth, offering valuable implications for policy formulation and strategic interventions to foster sustainable economic development.

Figure 4: Convergence and divergence of CTFP productivity between Morocco - Tunisia - United States



Source: Compiled by the author.

8.3. Beta convergence and sigma convergence: Formal cross-sectional Analysis

1- The absolute or unconditional convergence is estimated by estimating the parameter resulting from regression of the difference between the value of the at the end of the comparison period (tfp$\boldsymbol{i\,t}$) and its initial value at the beginning of the period (tfp$\boldsymbol{Y\,i\,,-T}$) on the initial value at the beginning of the period tfp$\boldsymbol{Y\,i\,,t-T}$ for cross-sectional data (for each country), as in the following equation:

(tfp$\boldsymbol{i\,t}$ −tfp$\boldsymbol{Y\,i\,,-T}$)=$\boldsymbol{\alpha}$ + $\boldsymbol{\beta}$ tfp$\boldsymbol{i\,,-T}$ +$\boldsymbol{\mu\,t}$ ……………..(1)

Whereas tfp$\boldsymbol{i}$ represents the productivity of country i in the year t, tfp$\boldsymbol{Y\,i\,,-T}$ represents the initial productivity value for country i at the beginning of the period t-T. Using the OLS method and obtaining the parameter □, and if □ it is negative and significant β<0, the hypothesis of absolute beta convergence is verified. If other variables $\boldsymbol{x}$ are added to the estimate, such as the investment rate, population growth, trade liberalisation, foreign direct investment, or institutional variables as in the following equation:

(tfp$\boldsymbol{i\,t}$ −tfp$\boldsymbol{Y\,i\,,-T}$)=$\boldsymbol{\alpha}$ + $\boldsymbol{\beta}$ tfp$\boldsymbol{i\,,-T}$ + $\boldsymbol{\gamma\,x\,i}$ + $\boldsymbol{\mu\,t}$ ………..(2)

If the parameter □ is negative and significant and if $\boldsymbol{\gamma} \neq 0$, the hypothesis of conditional beta convergence is fulfilled.

2- Estimating □ - convergence, which is determining whether the dispersion of the productivity index decreases over time, i.e. “the convergence hypothesis is met.” $\boldsymbol{\beta}$ is estimated by performing a regression of the standard deviation $\boldsymbol{\sigma t}$ for each year of cross-sectional data on the time variable t as follows:

$\boldsymbol{\sigma t} = \boldsymbol{\alpha} + \boldsymbol{\beta t} + \boldsymbol{\mu t}$ ……………………….(3)

The OLS method is used in estimation and should be negative and significant, β<0, in order to fulfil the assumption of convergence to sigma. However, to test sigma convergence, the hypothesis of beta convergence should be fulfilled first.

As shown in Table 4, the absolute beta $\boldsymbol{\beta}$ convergence test results reveal notable findings when considering the comparative Total Factor Productivity (TFP) index (CTFP) for the sample countries spanning the period from 1974 to 2019. Specifically, the probability values for the RTFP indicator indicate the insignificance of the Beta parameter, suggesting a lack of statistical significance in productivity convergence. However, for the CTFP indicator, the Beta parameter exhibits a negative and significant value. This implies that the hypothesis of absolute beta convergence can be tentatively accepted, albeit weakly, for the period 1974 to 2019 among the sampled Arab countries. The approximate equality of the Beta parameter to unity underscores a tendency towards convergence in productivity levels over the specified timeframe, albeit with some degree of variability.

Table 4: Results of the absolute beta $\boldsymbol{\beta}$ convergence test for Total Factor Productivity (TFP) CTFP for the sample countries for the period from 1974-2019

	RTFP (Relative total factor productivity index)		CTFP (Comparable total factor productivity index)	
Country	1974 $tfp_{i,t}$	1974-2019 $(tfp_{it} - tfpY_{i,t-T})$	1974 $tfp_{i,t}$	1974-2019 $(tfp_{it} - tfpY_{i,t-T}$
Egypt	1.6630	-0.6673	1.5097	-0.2829
Tunisia	0.9473	0.0358	0.9866	-0.1962
Morocco	1.1577	-0.1528	1.1847	-0.6566
Jordan	1.8053	-0.8420	0.9711	-0.1560
	Beta	Intercept	Beta	Intercept
Coefficient	-0.253	-0.028	-1.019***	1.014***
Prob	0.722	0.972	0.000	0.002

Source: Compiled by the author.

In Table 5, the absolute beta $\boldsymbol{\beta}$ convergence test results after dividing the study period into three distinct periods - 1974, 1989, and 2004 - provide further insights into convergence dynamics. The significance of the Beta parameter is noted primarily in the CTFP indicator, which remains negative and statistically significant across the specified time intervals. This reaffirms the hypothesis of absolute beta convergence, albeit with varying degrees of significance. Absolute beta $\boldsymbol{\beta}$ convergence test results value of the Beta parameter suggests a propensity towards convergence in productivity levels among the sample countries over time, indicating a potential trend towards alignment in economic performance. These findings contribute to a nuanced understanding of productivity dynamics within the sampled Arab countries, informing policy interventions to foster sustainable economic growth and development.

Table 5: Results of the absolute beta $\boldsymbol{\beta}$ convergence test for the Comparable total factor productivity convergence hypothesis CTFP for the sample countries over 3 time periods

	$tfp_{i,t}$	$(tfp_{it}-tfpY_{i,t-T})$	$tfp_{i,t}$	$(tfp_{it}-tfpY_{i,t-T})$	$tfp_{i,t}$	$(tfp_{it}-tfpY_{i,t-T})$
Country	1974	1974-1988	١٩٨٩	1989-2003	2004	2001-2019
Egypt	1.5096	-0.4816	0.9116	0.0788	0.9872	0.2396
Tunisia	0.9866	0.0120	0.9605	-0.2454	0.7061	0.0842
Morocco	1.1846	-0.2508	0.9426	-0.3410	0.5858	-0.0577
Jordan	0.9710	0.0039	0.9414	-0.4717	0.5241	0.2909
	Beta	Intercept	Beta	Intercept	Beta	Intercept
Coefficient	-0.929	0.901	-7.931	7.203	0.1920	0.005
Prob	0.011	0.017	0.315	0.327	0.75	0.991

Source: Compiled by the author.

The results of the visual examination in graphs (2), (3), and (4) are consistent with the hypothesis that the Beta convergence is fulfilled weakly and only during the period from 1974 to 1988, as demonstrated by the division of the period into three periods, as indicated in Table (6), and the use of the CTFP productivity index. The Beta parameter is statistically significant and negative, as is true, but it is rather near to the right value, Beta=-92. Estimating equation (3) to support the hypothesis convergence is useless, as we have already concluded weak beta convergence.

9. Empirical Results

Differences emerge between cross-sectional data and time series convergence in examining productivity convergence. Cross-sectional data convergence typically yields beta convergence, which is considered weaker than time series convergence due to susceptibility to what is known as the deception of rejecting the null hypothesis ("no convergence") when economies experience different states of steady state. Moreover, aggregate data over a long period may obscure convergence trends, potentially leading to deceptive conclusions. Cross-sectional analysis combines short-run dynamics with long-run characteristics, contributing to nuanced interpretations of convergence patterns.

In contrast, time series convergence entails the transitional reduction of differences in Total Factor Productivity (TFP) between countries or between a country and the mean of a group of countries over time. Random convergence in TFP necessitates that the time series of TFP differences between countries follows a stationary process. If the series exhibits stationary directionality, it indicates random convergence, whereas stationary series signify strong or specific convergence, often detected through unit root tests.

When examining convergence among a group of countries, the focus shifts to analysing time series characteristics to identify stationary components in the long run. Co-integration tests are crucial in assessing time series properties regarding stationarity or non-stationarity. Additionally, convergence analysis utilising panel data, which combines both time series and cross-sectional characteristics, requires unit root tests specific to panel data to evaluate convergence hypotheses effectively. These distinct methodologies offer complementary insights into productivity convergence dynamics across different analytical frameworks.

9.1. Unit Root Tests

The Dickey-Fuller-Test unit root test equation can be developed to test the hypothesis of long-run convergence and convergence as catching up. If we have two countries, p and q, each of which has productivity, which we will symbolise with the symbols $\boldsymbol{y_{p,t}}$ and $\boldsymbol{y_{q,t}}$, then the test equation will be as follows:

$$\boldsymbol{y_{p,t} - y_{q,t} = \mu + \alpha t + \rho\left(y_{p,t-1} - y_{q,t-1}\right) + \sum_{j=1}^{n} \delta_j \, \Delta(y_{p,t} - y_{q,t}) + \varepsilon_t} \text{---------(4)}$$

The symbol $\boldsymbol{\mu}$ expresses the constant, t expresses the direction, and its parameter is α; ρ expresses the unit root parameter. The symbol Δ represents the first differences of the dependent variable series.

From the values of equation (4) parameters and their significance, it is possible to test the convergence and distinguish between convergence in the long run and convergence as a catch-up process. The estimated parameters are interpreted as follows:

1) If the difference series $\boldsymbol{\left(y_{p,t-1} - y_{q,t-1}\right)}$ is non-stationary and includes the unit root, the parameter $\rho = 0$, then there is no convergence over time.

2) If the series $\boldsymbol{\left(y_{p,t-1} - y_{q,t-1}\right)}$ is stationary and does not include the unit root $\rho<0$, then there is convergence over time.

3) If the condition of rest $\rho<0$ is fulfilled and alpha is equal to zero $\alpha = 0$, there is no specific direction. The time parameter does not exist; this means there is convergence in the long run, and if alpha is not equal to zero $\alpha\neq0$, the convergence as catching up

hypothesis is fulfilled. That is, the difference in the presence of time is a deterministic direction.

By estimating equation (4) using the series of differences between the relative total factor productivity (CTFP) for each country and its corresponding for the United States, and by employing the Augmented Dickey-Fuller(ADF) test, it is clear from Table (6) that the significance of the two parameters ρ Egypt, in the absence of existence of the time direction α=0, and its condition α≠0, meaning that the series $\boldsymbol{y_{EG,t} - y_{US,t}}$ is stationary and does not include a unit root, and therefore the hypotheses of convergence in the long run and convergence as a process of catching up Egypt's relative productivity with the United States, during the period from 1974 to 2019.

Table 6 indicates the results of estimating equation (4) using the series of differences between the relative total factor productivity (CTFP) for each country and its corresponding value for the United States, along with employing the Augmented Dickey-Fuller (ADF) test. The significance of the two parameters, ρ Egypt, is noteworthy. When α equals zero, indicating the absence of a time trend, the parameter ρ Egypt is significant. Conversely, when α does not equal zero, implying the presence of a time trend, ρ Egypt remains substantial. This suggests that the series y_(EG,t) - y_(US,t) is stationary and does not include a unit root. Consequently, the hypotheses of convergence in the long run and catching up in Egypt's relative productivity with the United States from 1974 to 2019 are supported.

Table 6: Results of the long-run CTFP convergence test and convergence as a catch-up between the sample countries and the United States

Country	t-Statistic For the unit root parameter ρ in the absence of a time direction α=0	t-Statistic For the unit root parameter ρ in the presence of a time direction α≠0	the decision
United State			
• Egypt	-3.9236**	-3.9318**	There is convergence and catch-up.
• Tunisia	-1.3862	-0.0218	There is no convergence, and there is no catch-up.
• Morocco	-2.7429	-1.0933	There is no convergence, and there is no catch-up
• Jordan	-1.3506	-0.9656	There is no convergence, and there is no catch-up
Critical values	-2.929734	-3.515523	

Source: Compiled by the author.

However, the two hypotheses of convergence of productivity or catching up with the United States for Tunisia, Morocco and Jordan cannot be accepted because the calculated values of the t-statistic are less than the Critical values.

Table 7 reveals the results of applying the same test in Equation (4) to the differences between the sample countries' Comparable Total Factor Productivity (CTFP) as pairs. For instance, examining the differences between Egypt, Tunisia, Morocco, and Jordan separately. In the upper part of Table 7, the significance of the parameters for each pair is highlighted. A significant parameter suggests that the series of differences between the CTFP values for the respective pairs of countries is stationary and does not include a unit root. This finding implies potential convergence in the long run and suggests a process of catching up in relative productivity between the paired countries over the specified period.

Table 7: Results of the CTFP convergence test in the long run and convergence as a catch-up between the sample countries as pairs

Country	Unit root parameter in the absence of time direction $\alpha = 0$	Unit root parameter in the presence of time direction $\alpha \neq 0$	The decision
Egypt			
Tunisia	-1.7816	-1.792	There is no convergence and no catch-up.
Morocco	-1.0899	-2.2794	There is no convergence and no catch-up.
Jordan	-2.582	-2.8651	There is no convergence and no catch-up.
Tunisia			
Morocco	-3.2246**	-2.7707	There is convergence, and there is no catch-up
Jordan	-2.8047	-2.0894	There is no convergence and no catch-up.
Morocco			
Jordan	-2.019	-2.064	There is no convergence and no catch-up
Critical values	-2.929734	-3.515523	

Source: Compiled by the author.

Table (7) makes it evident that, except for the long-run productivity convergence between Tunisia and Morocco, which does not exhibit catch-up, the hypotheses of productivity convergence or catch-up between any two Arab countries in the sample cannot be accepted due to the calculated values of the t-Statistic being less than the critical values.

9.2.The Cointegration Test

Table 8 presents the results of the Johansen Cointegration Test within the framework of a multivariate Vector Autoregressions (VARs) model. The interpretation of Table 8 revolves around the concept of cointegration, which indicates the presence of equilibrium relationships in the long run between variables. The test is based on the premise that if a set of productivity time series for each country exhibits unit roots, indicating they are integrated of the first order (I(1)) but not stationary in their levels, then cointegration relationships may exist among them. The Johansen test determines the maximum number of cointegration relationships, denoted by r, equal to k-1, where k represents the number of productivity time series. A significant result for the Johansen test suggests that there are common stationary components among the non-stationary variables, providing evidence of equilibrium relationships in the long run. This finding supports the convergence hypothesis, indicating potential long-term equilibrium relationships between the productivity variables under investigation.

Table 8: Results of the unit root (ADF) test for the CTFP series for the sample countries

The decision	Variables as differences		Variables as levels		
	With Constant		Constant & Direction		With
	Prob.	t-Statistic	Prob.	t-Statistic	Country
First-order integral I (1)	0.0001	-5.1103	0.1969	-2.8231	Egypt
First-order integral I (1)	0.0001	-5.1694	0.9647	-0.7289	Tunisia
First-order integral I (1)	0.0000	-8.3066	0.9234	-1.0682	Morocco
First-order integral I (1)	0.0000	-6.7293	0.9355	-0.9897	Jordan

Source: Compiled by the author.

One of its most significant advantages is its ability to offer integration results under five different directions and constant models.

As demonstrated in Table 9, the results of the unit root test conducted for the real productivity series (CTFP) using the Augmented Dickey-Fuller (ADF) test unveil significant insights into the stationarity properties of the examined series for countries including Egypt, Tunisia, Morocco, and Jordan. Initially, all series were found to be non-stationary at their levels, indicating a need for more stability in their respective time series. However, upon taking the first differences, all series exhibited stationarity, implying that they are integrated of the first order (I(1)). This fundamental characteristic of integration is a prerequisite for conducting the Johansen test, which examines cointegration relationships among variables. Additionally, Table 9 summarises the integration test results across five Johansen models for the sample of four countries, employing a lag period of 2. It shows that the number of equal integration equations (CE) may be zero or one (r=1) across the five models. These findings contribute to a comprehensive understanding of the time series properties of real productivity among the sampled countries, laying the groundwork for further analyses exploring cointegration relationships and their implications for economic modelling and policy formulation.

Table 9: A summary of the results of the equal integration tests in the five Johannes models between the CTFP variable for each country in the sample attributed to the United States

Hypothesis:	Component	Form (1)	Form (2)	Form (3)	Form (4)	Form (5)
In the data	direction random	random	linear	linear		quadratic
In the CE integration equation	Constant	nothing	exist	exist	exist	exist
	direction	nothing	nothing	nothing	exist	exist
In the VAR equation	Constant	nothing	nothing	exist	exist	exist
	direction	nothing	nothing	nothing	exist	nothing

Number of CE integration equations	at 0.05 Critical Value				
Under Trace test	1	1	0	0	0
Under Max-Eig test	1	1	0	1	0

Source: Compiled by the author.

Whereas: CE: Cointegrating Equation, VAR: Vector Autoregression, Max-Eig: Maximum

After excluding Form (4) due to conflicting results From the Trace effect test and the Maximum Eigenvalue test, Models (1) and (2) demonstrate a single integration relationship between the productivity chains of the four countries, denoted by r = 1. This signifies acceptance of the hypothesis of random productivity convergence in the long run among the sample countries. Conversely, models (3) and (5) indicate the absence of an integration relationship, with r = 0, rejecting the hypothesis of absolute productivity convergence in the long run between the sample countries. These findings from the Johansen Cointegration Test suggest that random convergence is observed between the sample countries and the United States, affirming the application of the hypothesis of random convergence in productivity dynamics among the sample countries.

9.3. Testing Convergence: A Panel Data Approach

According to Evans and Karras (1996), the convergence hypothesis can be tested using panel unit root tests (PURT) as follows:

We assume that we have a sample of countries 1,2, N, and it is believed that they have the same level of technological knowledge, but each economy in the sample has a unique steady state. In this case, convergence is achieved if the deviation between the

Country's productivity and its stable or mean productivity is temporary in the long run. To clarify:

We assume that we have the productivity index tfp$\boldsymbol{n}$,+$\boldsymbol{i}$ for country n in period t, $\overline{\boldsymbol{tfp_{n,t+1}}}$ represents the mean of the sample with which countries n participate, and according to the Solow model, the limit of the expected value of the difference between them (tfp$\boldsymbol{n}$,$\boldsymbol{t}$ +$\boldsymbol{i}$ – top* $\boldsymbol{t}$ +$\boldsymbol{i}$) should be equal to a constant amount μn ﻭor a steady state as i approaches infinity, as expressed in the following equation:

$$\boldsymbol{lim_{i\to\infty}\, E_t\left(tfp_{n,t+1} - \overline{tfp_{n,t+1}}\right) = \mu_n} \qquad n=1,\ldots, N\text{-------------}(5)$$

Whereas μn represents the deviation that should be equal to a fixed amount when i equals infinity, and the deviation is of non-zero value, but its mean is equal to zero. In other words, the productivity convergences of an economy will lead to a steady state value in the long run.

Thus, the absolute convergence is achieved when - and only - the value $\boldsymbol{\left(tfp_{n,t+1} - \overline{tfp_{n,t+1}}\right)}$ for a country is greater than the productivity growth rate in rich countries, and catch-up is also achieved. We say that this convergence is a conditional convergence when μ$\boldsymbol{n}$ does not equal zero μ_n≠0, as each country's productivity converges to its mean value in the long run.

Unit root tests are used for PURT panel data, which assume that there are no fixed individual effects for each country; that is, a common unit root is tested to test the hypothesis of unconditional, absolute convergence, while unit root tests for panel data, which assume the presence of fixed individual effects for each country, are used to test the conditional convergence hypothesis.

Two generations of unit root tests exist for Panel Unit Root Tests (PURT). The first generation operates under the assumption of no cross-sectionally independent association among the remainder of the panel series, typically applied to variables like productivity. Notable tests within this generation include those proposed by Levin, Lin & Chu (2002); Im, Pesaran and Shin (2003); Maddala and Wu (1999); and Hadri (2000) (Abbas & Nasir, 2001; Hadri, 2000; Im et al., 2003; Levin et al., 2002; Maddala & Wu, 1999).

However, Phillips and Sul (2003) argue that this assumption of cross-sectional non-independence (CSD) is unrealistic, particularly when testing convergence hypotheses or conducting purchasing power parity analyses. They point to the influence of overarching factors such as recession, business cycles, and financial crises on variable behaviour, challenging the validity of the assumption. Consequently, the second generation of unit root tests for PURT panel data emerged to address this issue (Phillips & Sul, 2003).

These tests, such as the Panel Analysis of Nonstationary in Idiosyncratic and Common Components (PANIC) test proposed by Bai and Ng (2004) and the Cross-sectionally Augmented IPS (CIPS) test introduced by Pesaran (2007), operate under the assumption of a connection between the remaining cross-sectional dependence (CSD) panels of the variable. This advancement aims to provide a more realistic assessment of unit root behaviour in panel data, accounting for potential cross-sectional dependencies that may influence variable dynamics (Bai & Ng, 2004; Pesaran, 2007).

First: Description of Bai and Ng's (2004) PANIC test.

In brief, the PANIC unit root testing algorithm presented by Bai and Ng (2004) includes three steps: calculating the common factors and idiosyncratic components, testing the unit root on the distinct elements, and testing the unit root on the common factors. This separation of common factors allowed the test to assume that there is a strong correlation between the cross-sectional data while at the same time restricting the test to the rest of the data having a low correlation (Bai & Ng, 2004). Thus, the PANIC test is based on decomposing the panel series into the three components shown in the following equation:

$$y_{i,t} = D_{i,t} + \lambda_i^{/} F_t + e_{i,t} ---------- (6)$$

Whereas: $y_{i,t}$ is the productivity series for each country, $D_{i,t}$ is a polynomial time function of order t, F is a vector (r; 1) of the common factors (specific heterogeneous component), $\lambda_i^{/}$ Parameters of common factors, $e_{i,t}$ Components are idiosyncratic components.

In this case, $y_{i,t}$ is said to be non-stationary if at least one common factor of the vector Ft is non-stationary, and the idiosyncratic Component $e_{i,t}$ is non-stationary.

Then Bai and Ng (2004) replaced the effects with a constant $\propto_i$ instead of the specified component $D_{i,t}$ in equation (8)

$$y_{i,t} = \propto_i + \lambda_i^{/} F_t + e_{i,t} \qquad t = 1 \ldots, T - - - - - - (6.1)$$

The equation for each common factor $F_{m,t}$ can be written as

$$F_{m,t} = \tau_m F_{m,t-1} + v_{m,t} \qquad m = 1 \ldots, \tau - - - - - - (6.2)$$

The equation of the error run component $e_{i,t}$ can also be written as follows:

$$e_{i,t} = \rho_i e_{i,t-1} + \epsilon_{i,t} \qquad i = 1 \ldots, N - - - - - - (6.3)$$

The m th component is at rest whenτ_m<1, and the error run for the i-th state is at rest whenρ_i<1

The m th common component is stationary when $\tau_m < 1$, the error limit for the country i th is stationary when $\rho_i < 1$

But the values of $F_{m,t}$ and $e_{i,t}$ are not observed and should be calculated. Bai and Ng (2004) proposed obtaining them by estimating the common factors on the first differences of the data and then calculating the cumulative sum of the estimated factors and accumulating these estimated factors (Bai & Ng, 2004). Suppose the number of common factors r is known or calculated using the principal component method. From the following first difference equation:

$$\Delta y_{i,t} = \lambda_i^{/} \Delta F_t + \Delta e_{i,t}$$

The estimated value $\widehat{F}_{m,t}$ is calculated by the formula: $\widehat{F}_{m,t} = \sum_{s=2}^{t} \Delta \widehat{F}_{m,s}$

We calculate the estimated value of the remainders: $\hat{e}_{i,t} = \sum_{s=2}^{t} \Delta\hat{e}_{i,s}$

The final step is:

1) Testing the stationary of the common components F by using the equation:

$$\Delta\hat{F}_{m,t} = c + \gamma_{i,0}\hat{F}_{m,t-1} + \gamma_{i,m}\Delta\hat{F}_{m,t-1} + .. + \gamma_{i,p}\Delta\hat{F}_{m,t-p} + v_{i,t}$$

2) Use the following equation to test the unit root in the error run component for each country separately without a constant and assuming there is no correlation between them:

$$\Delta\hat{e}_{1,t} = \delta_{i,0}\hat{e}_{i,t-1} + \delta_{i,1}\Delta\hat{e}_{i,t-1} + .. + \delta_{i,p}\Delta\hat{e}_{i,t-p} + \mu_{i,t} \quad ------(7)$$

The null hypothesis, which is the absence of stationary condition or the presence of a unit root in the remainder of the panel productivity series $e_{i,t,}$ is:

H 0 : $\delta_{i,0} = 0$ for all i = 1,…,N

Instead of the alternative hypothesis, which is stationary or the absence of a unit root in $e_{i,t}$ for some international I H1: $\delta_{i,0}<0$,

This means that the alternative hypothesis is the presence of the unit root in some countries of the group and its absence in others.

If it is assumed that there is one common component $\hat{F}_{1,t}$, the following equation is used to test the unit root of this component:

$$\Delta\hat{F}_{1,t} = c + \gamma_{i,0}\hat{F}_{1,t-1} + \gamma_{i,1}\Delta\hat{F}_{1,t-1} + .. + \gamma_{i,p}\Delta\hat{F}_{1,t-p} + v_{i,t} \quad --(8)$$

Whereas: H0 : γ_(i,0) = 0 for all i = 1,…,N,

For some i H1 : γ_(i,0) < 0

Second: Description of the Pesaran tests

Instead of decomposing the series into several common factors, the Pesaran tests assumed that there is one common factor $\bar{y}_{t-1}$ and used the following equation to test the residuals:

$$\Delta y_{i,t} = \alpha_i + \rho_i y_{i,t-1} + c_i \bar{y}_{t-1} + \rho_i \Delta \bar{y}_t + v_{i,t}$$

Whereas: $\bar{y}_{t-1} = (\frac{1}{N}) \sum_{i=1}^{N} y_{i,t-1}$, and: $\Delta \bar{y}_t = (\frac{1}{N}) \sum_{i=1}^{N} \Delta y_{i,t}$

Then, the t-statistic for the parameter $\rho\, i$ is calculated $b\,y$ using the ADF method for each country. It is presented under the symbol CIPS, and CIPS* for truncated data and is called truncated version.

The null hypothesis, which is the absence of rest or the presence of the unit root, is:

H 0 : $\rho_i = 0$ for all i = 1,…,N

Against the alternative hypothesis, which is the stationary case or the absence of a unit root for some countries i: H1: ρ_i<0,

This means that the alternative hypothesis also includes the presence of the unit root in some countries of the group and its absence in other countries.

Third: Results of the Cross-sectional Dependence (CSD) test

As depicted in Table 10, the results indicate the inability to reject the null hypothesis, suggesting no correlation in the productivity series across the five countries examined. Conversely, the alternative hypothesis proposing reliability and correlation in the series data must be supported. This finding underscores the limitations of employing first-generation unit root tests in panel data analysis, highlighting the necessity for utilising second-generation tests such as PANIC (Panel Analysis of Nonstationarity in Idiosyncratic and Common components) and CIPS (Cross-Sectionally Augmented IPS) to ensure the validity of the analysis. The absence of significant correlation in the productivity series across countries suggests a nuanced understanding of the interplay of factors influencing productivity dynamics, necessitating robust methodologies to accurately assess cross-country relationships and their implications for economic modelling and policy formulation.

Table 10: Results of the Cross-Section Dependence Test for the variable CTFP

Null hypothesis: No cross-section dependence (correlation)		
Sample: 1976 2019, Periods included: 44, Cross-sections included: 4, Total panel observations: 176		
Test	Statistic	Prob.
Pesaran scaled LM	23.66	0.000
Pesaran CD	7.74	0.000

Source: Compiled by the author.

Fourth: Results of the convergence test for panel data

The table shows the results of the PANIC non-stationary test for the CTFP variable productivity panel series. For ease of interpretation and comparison with the CIPS test results, the test was done under one common factor affecting the series, according to Ahn and Horenstein (2013) (Ahn & Horenstein, 2013). The table shows that the common factor affecting the series is not in the stationary case under the section only. Still, it turns into the stationary case when the direction is added according to the values of the t-statistic and the probability values of the p-value of the parameter Component $\boldsymbol{F1,t-1}$, which is $\boldsymbol{\gamma i,0}$ in the equation (10), from the test $\boldsymbol{ADFF}$ in the table (11).

Table 11 reveals the results of the $\boldsymbol{ADF_{\hat{F}}}$ test conducted to assess the stationarity of the common factor affecting the series in the context of the PANIC non-stationary test for the CTFP variable productivity panel series. The table demonstrates that the common factor influencing the series exhibits non-stationarity in isolation, as indicated by the t-statistic and probability values of the p-value associated with the parameter Component **in the** equation. However, the common factor transitions into a stationary state upon incorporating the time direction. This transformation suggests that adding directionality to the analysis alters the behaviour of the common factor, leading to a more stable and stationary condition.

Table 11*:* Results of the PANIC non-stationary case test for the panel series for the CTFP variable

Unit root in:	test	constant		Constant and direction	
		t-statistic	p-value	t-statistic	p-value
Common factor	$ADF_{\hat{F}}$	-2.328	0.155	-3.42***	0.001
Idiosyncratic	$ADF_{\hat{e}}$	t-statistic	p-value	t-statistic	p-value
cross-section: Egypt		-0.483	0.516	-0.884	0.878
cross-section: Tunisia		0.059	0.703	-0.860	0.890
cross-section: Morocco		1.410	0.963	-0.795	0.922
cross-section: Jordan		-0.680	0.430	-0.941	0.847
Pooled statistic		-1.023	0.306	-1.753*	0.079

Source: Compiled by the author.

As illustrated in Table 12, the results of the non-stationary case tests conducted On the series of idiosyncratic elements for the four countries reveal a consistent pattern of non-stationarity. This indicates a need for more stability in these specific components across the examined countries. Notably, the significance of the pooled statistic parameter, which evaluates the hypothesis concerning the absence of cointegration between the productivity of the four countries, emerges when time is factored into the analysis. Specifically, the parameter is significant at a level below 10%. Consequently, the hypothesis suggesting no cointegration between the productivity levels of the four countries can be tentatively accepted, albeit weakly. This observation supports the notion of random convergence, implying a tendency towards convergence in productivity levels among the sampled countries, albeit with varying degrees of significance. These findings contribute to a nuanced understanding of cross-country productivity dynamics, offering valuable insights for policymakers and researchers in navigating efforts to foster sustainable economic growth and development.

Table 12*:* CIPS non-stationary case test results for the panel series for the CTFP variable

Unit root in:	Test	constant		Constant and direction	
		t-statistic	p-value	t-statistic	p-value
Truncated	*CIPS*	-2.498**	<0.05	-3.687***	<0.01
cross-section: Egypt	*CADF*	-3.154**	<0.10	-3.537**	<0.10
cross-section: Tunisia	*CADF*	-3.045**	<0.10	-4.057**	<0.05
cross-section: Morocco	*CADF*	-1.183	>=.10	-3.137	>=.10
cross-section: Jordan	*CADF*	-2.613	>=.10	-4.016	<0.05

Source: Compiled by the author.

9.4. Estimates of Determinants of Total Factor Productivity Convergence

9.4.1. Description of the Variable Selection Method and the results of the selection

According to prior research, productivity convergence is influenced by various potential variables, including trade openness, foreign direct investment, savings and investment ratios to output, as well as factors such as the cost of capital, inflation rate, exchange rate, population growth, number of workers, and worker productivity. Therefore, the pertinent question arises: which variable or variables exert the most significant influence on productivity convergence among the sample countries and the leading country, namely the United States, or productivity convergence between them?

To address this question, the Variable Selection and Stepwise Least Squares (VARSEL) method can be an initial approach for selecting suitable explanatory variables for estimation. This method encompasses five distinct techniques for variable selection. The first method is Uni-directional selection, which employs either the p-value criterion or the t-statistic value as a criterion for incorporating explanatory variables into the estimation process. It includes both the forward method, which initiates estimation without any potential explanatory variables and subsequently adds variables with the lowest p-value or highest t-statistic value, and the backward method, which begins estimation with all possible explanatory variables and subsequently removes the variable with the highest p-value or lowest t-statistic value.

The second approach involves Automatic Search from General to Specific (Auto-Search/GETS), which bears similarities to Uni-directional-backwards selection. As defined by Escribano and Sucarrat (2011), this method progresses through steps encompassing a gradual refinement from a general model to a specific one (Escribano & Sucarrat, 2011):

The model is initially estimated using the general unrestricted model (GUM), incorporating all research variables, followed by a series of diagnostic tests to assess its validity. These tests include the AR LM test for residuals, the ARCH LM test for the squares of residuals to examine significance and lag periods, the Jarque-Bera normality test to assess the distribution's normality, and the parsimonious encompassing test (PET) to evaluate the overall significance of the model. Subsequently, non-significant variables identified from the GUM estimate are targeted for removal, initiating a process where each path undergoes variable elimination steps until diagnostic tests are satisfied. Suppose a diagnostic test fails after removing a variable. In that case, it is reinstated into the model, and variable removal continues until all variables become significant or further removal compromises diagnostic test results. Once all trajectories are computed, the resulting final models are compared using information parameterisation to select the optimal model.

Throughout this process, diagnostic tests are conducted using EViews to ensure the reliability and accuracy of model selection.

The stepwise selection encompasses two methods: Stepwise-Forwards and Stepwise-Backwards. Stepwise-forwards initiates without any explanatory variables and progressively adds variables based on their p-values, with subsequent comparison against a backward p-value criterion to remove variables. Stepwise-Backwards, conversely, includes all possible variables initially and removes those with the highest p-values, subsequently assessing them against a forward p-value criterion for potential reinstatement. Combinatorial selection evaluates every possible set of added variables to determine the set leading to the highest coefficient of determination (R2) or excludes the set resulting in the lowest R2 value. Lasso selection employs the Least Absolute Shrinkage and Selection Operator (Lasso) estimator, which utilises the OLS method with an imposed penalty to shrink parameters towards zero, thereby addressing overfitting concerns stemming from excessive variables in the regression equation.

Estimates of Determinants of Comparative Factor Productivity Convergence (CTFPG): As demonstrated in Table 13, the estimation results using the VARSEL method offer significant insights into the determinants of total factor productivity growth (CTFPG) and the hypothesis of convergence between the productivity of the sample countries and that of the United States. Among the eight variables initially considered, namely the human capital index (HC), internal rate of return on capital balance (IRR), logarithm of market exchange rate (LnXR), logarithm of factor productivity index (Ln(GDP/EM) in US dollars), population growth rate (LnPOP), proportion of foreign direct investment to FDI output, degree of trade openness (OT), and inflation rate (INF), several were excluded based on their impact on the estimation outcomes. Population growth rate, degree of trade openness, market exchange rate, and inflation rate were deemed irrelevant. Their inclusion resulted in either decreased coefficient determination (R2) and explanatory power of the estimated equation or reduced t-statistic value and increased p-value of other variables. These variables exhibited no discernible effect on CTFPG, with their parameters converging to zero according to the Lasso method. This meticulous selection process refines the understanding of the drivers of productivity growth and underscores the significance of identifying pertinent variables in modelling convergence dynamics across countries.

Table 13: VARSEL estimation results for selecting the most important variables explaining total factor productivity growth (CTFPG) growth.

Selection method / Variable	Auto search-Gets	Uni-directional-Forwards Stepwise forwards	Lasso	Combinatorial
	Coefficient [Std. Error]	Coefficient [Std. Error]	Coefficient [Std. Error]	Coefficient [Std. Error]
Constant	-0.27*** [0.08]	-0.26*** [0.08]	-0.25*** [0.11]	-0.32*** [0.08]
Ln(GDP /EM)	0.02** [0.01]	0.02** [0.01]	0.02** [0.01]	0.03*** [0.01]
FDI/GDP	0.42*** [0.15]	0.43*** [0.15]	remove	remove
IRR	Remove	0.07* [0.05]	remove	remove
HC	remove	Remove	0.01* [0.01]	remove
LnPOP	remove	-0.25 [0.36]	remove	remove
INF	remove	remove	remove	remove
LnEX	remove	remove	remove	remove
OT	remove	remove	remove	remove
Adjusted R^2	0.104	0.11	0.07	0.07
Durbin-Watson stat	2.00	2.03	1.91	1.89

Source: Compiled by the author.

The study found that the rate of openness (OT) did not significantly impact productivity growth and convergence in Arab countries because most imports were consumer goods, and the sample countries' lack of institutional development strategies hindered their ability to capitalise on global market opportunities. (Escribano & Sucarrat, 2011). The lack of capabilities to effectively allocate resources and the low absorptive capacity allow it to absorb the indirect effects of trade liberalisation (McNeil, 2014).

The lack of impact of the LnEX market exchange rate on productivity growth and its convergence can be explained by the following reasons: The LnEX market exchange rate is controlled, creating uncertainty and impacting real investor and FDI decisions. The exchange rate's effect on growth or productivity is determined by financial development, with weak indicators in depth and breadth in sample countries, as per Aghion et al. (2009) (Aghion et al., 2009). The lack of influence of the inflation rate on productivity growth and its convergence can also be explained by the fact that the cause of inflation in the sample countries is due to attracting demand (aggregate demand) and not paying expenses (supply side).

The logarithm of the factor productivity index, Ln(GDP/EM), emerges as a consistently significant variable across all selection methods, positively influencing productivity growth in the four sample countries. This underscores the pivotal role of worker productivity as the primary economic factor driving convergence between the productivity levels of Arab countries and the United States. Conversely, the ratio of foreign investment to output (FDI/GDP) demonstrates a substantial, positive impact on relative productivity convergence, as indicated by the parameter's significance and magnitude. However, despite its initial significance, FDI/GDP is excluded under the Lasso method due to its parameter shrinking to zero upon imposition of a penalty condition. Moreover, its inclusion in the group of explanatory variables yields the lowest R2 value for the regression equation according to the combinatorial selection method.

As depicted in Table 14, the disproportionate impact of foreign direct investment (FDI) on productivity convergence within the sample of Arab countries can be attributed to various factors, including the nature of FDI inflows. Notably, the FDI/GDP rate exhibits unusually high and abnormal rates in certain years of the study period, particularly in Jordan. For instance, Jordan recorded remarkably high FDI/GDP rates of 15.8% in 2005, 23.5% in 2006, and 15.3% in 2007, significantly surpassing the mean rate of 3.8% observed during the study period. Excluding periods of high fluctuations, the mean rate drops to 2.3%. Similarly, Egypt also demonstrates elevated FDI/GDP rates, albeit to a lesser extent. This observation underscores the volatility and potentially erratic nature of FDI inflows, which may lead to disproportionate impacts on productivity convergence efforts. Such fluctuations in FDI rates highlight the need for robust policy frameworks to effectively harness foreign investment for sustainable economic growth and productivity enhancement across the sampled Arab countries.

Table 14: The fluctuation of the foreign investment index to the output (FDI/GDP) in the sample countries

Mean FDI/ GDP over:	Egypt	Tunisia	Morocco	Jordan
Study period 1976-2019	2.8 %	2.3 %	1.4 %	3.8 %
Period 2000-2009	5.9 %	4.5 %	2.4 %	14.2 %
The study period excluding the period 2000-2009	1.7 %	2.0 %	1.3 %	2.3 %

Source: Compiled by the author.

FDI may not positively impact factor productivity if MNCs operate in uncompetitive sectors or if implemented in a context that weakens domestic investment and savings. This can restrict investment and reduce external balances due to profit repatriation to home countries. Limited exports in FDI designed for domestic consumption can negatively affect the current account balance and foreign reserves.

The impact of the human capital index (HC) and the internal rate of return on the capital balance (IRR) on productivity growth was insignificant. This implies that despite the consideration of per capita human capital, based on the mean number of years of education, education expenditures still needed to improve its quality. Similarly, the lack of significance in the effect of IRR, which reflects the cost of acquiring capital or the unit price of capital, suggests a potential scenario of diminishing capital productivity. The neutral effects of these variables on productivity may stem from a balance between their positive and negative influences on productivity convergence.

The constant parameter exhibited substantial significance across all tests, presenting a notable negative impact on the convergence of relative productivity. This implies that country-specific factors exert a detrimental influence on productivity convergence. Moreover, the findings suggest that the proximity of Egypt, Tunisia, Morocco, and Jordan's productivity levels to that of the United States is primarily attributed to worker productivity, yielding a positive effect. Additionally, while the inflow of foreign direct investment relative to domestic product showed a positive impact, its influence appeared to be constrained. These insights underscore the nuanced interplay between factors shaping productivity convergence among the sample countries.

9.4.2. Estimates of Determinants of the Convergence of Real Factor Productivity (RTFPG)

Table 15 presents the estimation outcomes utilising the VARSEL method to identify the most influential variables elucidating real factor productivity growth (RTFPG) growth, comprising the same eight variables as in previous analyses. The results offer insightful conclusions: the factor productivity EMP/GDP, human capital index (HC), internal rate of return on capital balance (IRR), degree of trade openness (OT), and market exchange rate (LnXR) were omitted from the estimation due to their adverse impact on the analysis. These variables, upon inclusion, either diminished the coefficient of determination (R2) and explanatory power of the estimated equation, reduced the t-statistic value, or elevated the probability value (p-value) of other variables, indicating their lack of significant impact on productivity growth. This discernment underscores the importance of refining variable selection to capture the most salient determinants of productivity growth, facilitating a more nuanced understanding of the factors driving real-factor productivity dynamics.

Table 15: VARSEL estimation results for selecting the most important variables, which explain real factor productivity growth (RTFPG) growth**.**

Selection method Variable	Auto search-Gets	Uni-directional-Forwards Stepwise forwards	Lasso	Combinatorial
	Coefficient [Std. Error]	Coefficient [Std. Error]	Coefficient [Std. Error]	Coefficient [Std. Error]
Constant	0.01 [0.01]	0.01 [0.01]	0.01 [0.01]	0.01 [0.01]
Ln(GDP /EM)	remove	remove	remove	remove
FDI/GDP	0.24** [0.09]	0.22** [0.09]	remove	remove
IRR	remove	remove	remove	remove
HC	remove	remove	remove	remove
LnPOPG	-0.90*** [0.23]	-0.85*** [0.24]	-0.82*** [0.23]	-0.82*** [0.23]
INF	remove	-0.05 [0.05]	remove	remove
LnEX	remove	remove	remove	remove
OT	remove	remove	remove	remove
Adjusted R^2	0.09	0.09	0.06	0.06
Durbin-Watson stat	2.10	2.10	2.10	2.10

Source: Compiled by the author.

In all selection methods, the population growth rate indicator (LnPOP) emerged as the primary variable, displaying a significant negative effect on real productivity growth across the four sample countries. This adverse impact can be attributed to the rise in the proportion of the population within age groups under 15 years and above 60 years. Conversely, foreign investment inflows exhibited a positive and significant effect on both real productivity and relative productivity growth. However, the inflation rate did not significantly influence real productivity and was consequently excluded by both the Lasso and Combinatorial methods. Moreover, the insignificance of the constant parameter in all methods suggests that country-specific differences do not significantly impact real productivity. Consequently, it can be inferred that real productivity convergence among Egypt, Tunisia, Morocco, and Jordan is primarily driven by the population growth rate (LnPOP), with the effect of foreign direct investment (FDI) being relatively limited.

10. Conclusion

In conclusion, this study delves into the critical examination of the convergence hypothesis of total factor productivity (TFP) among Egypt, Tunisia, Morocco, and Jordan, as emerging economies, compared with the United States, while exploring the determinants influencing such convergence. The findings reveal nuanced insights: while absolute beta convergence was weakly accepted over the period 1974-2019, indicating a sluggish pace of convergence,

the hypothesis of catch-up with relative productivity was confirmed between Egypt and the United States. However, such convergence was not evident among the Arab countries in the sample, except for long-run productivity convergence between Tunisia and Morocco. Cointegration tests further underscored the random convergence hypothesis, debunking the notion of specific convergence. Cross-sectional dependence analysis validated interconnections within productivity series across the five countries. Additionally, employing second-generation unit root tests highlighted the absence of a unit root in the CTFP series for Egypt and Jordan only, suggesting random convergence solely with the United States. The Variable Selection and Stepwise Least Squares (VARSEL) method revealed that worker productivity primarily drives convergence to US productivity. In contrast, real productivity convergence is linked to population growth rates. However, macroeconomic variables elucidated a modest explanation of changes in productivity growth, emphasising the need for institutional focus. Recommendations advocate for leveraging trade liberalisation through strategic institutional development and enhancing absorptive capacity, attracting competitive FDI inflows, improving financial development indicators, and prioritising investment in human capital quality to foster sustainable productivity growth and convergence.

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