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Research article

Modeling economic growth factors in Egypt: A quantile regression approach

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ABSTRACT

This paper investigates the sources of Egypt's economic growth over the course of four generations of reforms from 1991 to 2019. To examine the contribution of input factors to economic growth, we used the augmented Solow model, which includes both human and physical capital accumulation. Variables employed in the analysis are Gross Domestic Product, capital, productivity, human capital, and employment. The study uses quantile regression econometric modeling to examine the sources of growth in the Egyptian economy at various stages of reform and the convergence of income segmentations. Quantile Regression (QR) estimates for quantiles 0.1 through 0.9 showed varied results. Productivity's coefficient increased from 0.27 in Q1 to 0.60 in Q8 which means that productivity has clearly had a large impact on the higher stages of economic growth. In addition, the higher income segmentations we go, the higher impact of productivity it gets. However, Capital and Human Capital go in the opposite direction where coefficients of capital deteriorated gradually from 0.3 in Q1 to 0.1 in Q9, and coefficients of human capital decreased from 0.15 for Q1 to reach 0.04 for Q9. Therefore, the main culprit behind this phenomenon is the deficiency in the savings rate and the increase in the population growth rate. For labor, its coefficient is negative all the time. It declined from −1.03 for Q1 to −1.46 for Q9. It indicates that the Egyptian economy is filled with disguised unemployment and exhausts all its potential for job creation. Moreover, this evidence indicates that productivity and human capital accumulation have become the most important sources of growth. The weak growth performance is attributed to the deficiency of investment in both physical and human capitals. Furthermore, the findings show that economic growth is closely linked to trends in human capital, productivity, and capital, all of which are heavily influenced by savings volatility and population growth rates. Therefore, the Egyptian economy's economic growth cycle is determined by savings and population growth rates. When these rates become in the trends enabling human capital, productivity, and capital to boom, strong capital accumulation appears and boosts economic growth and vice versa.

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1. Introduction

Economists have always been drawn to economic growth to understand better how it is achieved. Several questions have been proposed in this regard to obtain answers. For instance, what growth model does the economy follow? Why are there fluctuations in economic growth path in a specified economy? What factors cause some countries to grow at a faster rate than others? Numerous theoretical and applied research papers in the literature have analyzed the process of economic growth in both developed and developing countries. Indeed, in the case of developing countries and emerging markets, the importance of analyzing the evolution of economic growth is amplified. The main reason for this is the belief of the vast majority of economists that economic growth is the optimal way to alleviate poverty and achieve long-term development.

In Egypt, an urgent question has been raised about the main causes of economic booms and busts. Note that the Egyptian economy's status of economic stagnation during the 1980s quickly recovered during the first half of the 1990s decade. However, from 1998 to 2004, the economy was once again jolted by another recession. Moreover, the same pattern repeated itself with economic recovery during the second half of the first decade of the 2000s and a downward recession in the decade following the 2011 revolution.

Unfortunately, only few research papers, such as Kheir-El-Din and Moursi [1] and Kamaly [2], have focused on the Egyptian economy's economic growth formulation. They claimed that Egypt's growth is erratic, with a sporadic pattern emerging. The Egyptian economy has experienced ups and downs in terms of economic growth over in the last four decades. Furthermore, Egypt's population growth has been consistent and accelerated at high rates during these decades. As a result, the Egyptian economy is being burdened by mismanaged and irrationalized increased population growth combined with volatile economic growth. Egyptian officials have always used this to justify and attribute the country's economic stagnation, which dates back to the early 1980s.

1.1. Four generations of reform starting 1991

Egypt began its economic reform program in 1991, in cooperation with the International Monetary Fund and World Bank. Consequently, Egyptian governments have continued to liberalize the economy and markets to implement a market-oriented economic system. Egypt experienced four generations of economic reforms from 1991 to 2020, all of which followed the same economic approach.

1.1.1. The first generation of economic reform (1991–2000)

The four generations of economic reform can be characterized to begin in 1991 and end in 2000. This reform program, known as Economic Reform and Structural Adjustment Program (ERSAP), set its main objectives to achieve structural adjustment, economic stabilization, and boost sustainable economic growth. As a result, Egypt's government has adopted a plan to move closer to a market-oriented economy by reducing the government's role in economic activities. The Egyptian economy was impacted by shocks caused by external and internal crises during this time, thus necessitating these reforms. Between 1997 and 1999, the East Asian financial crises happened. This severe external crisis was accompanied by many domestic crises, including the 1997 terrorist attack in Luxor. Undoubtedly, these international and domestic crises have negatively impacted economic growth.

1.1.2. Second generation of reform (2000–2005)

The second generation of reform was the era of institutional and legal reforms. However, economic performance was stagnant. Banking crises known as "loan deputies" harmed the economy during this period, preventing foreign direct investment (FDI) proceeds and eroding economic growth.

1.1.3. Third generation of reform (2005–2010)

Since 2004, Egypt has accelerated its pace toward shifting its economy to work under the liberal economic system based on the free market mechanism.

Two economic policies have played a critical role in Egypt's economic growth during this period. First, the government expanded the private sector's role in the economy and the market-oriented economic system, allowing for more private sector involvement and partial liberalization of the trade sector and the exchange rate regime. Second, a significant increase in windfall revenues from the privatization program, the tourism industry, and FDI proceeds boosted the national income. Naturally, the rapid growth in tourism revenues and worker remittances from outside Egypt enabled the Egyptian government to build up international reserves of US dollars (USD), which peaked at around 36 billion USD in 2010.

Consequently, these large international reserves enabled the Egyptian Central Bank to control the exchange rate market and made a remarkable contribution to the country's rapid economic growth. However, by the end of 2010, the Egyptian economy's major structural imbalances had not been addressed. As a result, the January 2011 public revolution was a logical uprising.

1.1.4. Fourth generation of reform (2011–2020)

The fourth generation of economic reform in Egypt can be divided into two phases:

Phase 1 (2011–2014): The economic growth rates are low because of the Two Revolutions in Egypt: Economic growth during this period averaged around 2.3% per year, and by the end of 2014, the unemployment rate had risen to around 12.9% (Egyptian Ministry of Finance, 2015).

Phase 2 (2014–2020): This phase is the Egyptian economy under a new regime: Starting June 2014, the Egyptian government has implemented a bold economic reform program where the economic growth rate improved from 4.2% to 5.3% during the 2017/2018 fiscal year because of the rise in aggregate investments and several improvements in the infrastructure.

Unfortunately, from 2011 to 2014, there was no progress in terms of the promised and expected economic recovery. Unfortunately, the economic downturn persisted, and the gross domestic product (GDP) growth did not exceed 2%. Furthermore, the unemployment rate remained high, and inflation remained in the double digits [3].

Due to the scarcity of research papers on this topic, this study aims to clarify and analyze the sources of economic growth in the Egyptian economy over the last thirty years. The work of Kheir-El-Din and Moursi [1], who studied the 1960–1998 period, and Kamaly [2], who investigated the 1974–2002 period, were the only two studies conducted. Hence, this research attempts to fill several gaps in the literature. First, a sample of data from 1991 to 2020 will be used in this research. Second, to our knowledge, this is the first study to use quantile regression to analyze economic growth in Egypt.

Moreover, the vast majority of empirical research papers employed ordinary least squares (OLS) econometric modeling, which simulates the mean of the growth rate conditional to many independent variables. Meanwhile, quantile regression (QR) is used in this study to investigate the sources and determinants of economic growth across various quantiles of economic growth. Furthermore, QR modeling outperforms OLS modeling for various reasons. First, QR estimations are robust to outliers in the dependent variable. The advantage here is that growth rates have long right tails, which negatively affects the OLS estimations [4–6]. The second benefit of QR modeling is that it allows researchers to investigate the effects of independent variables on different quantiles of the dependent variable. Consequently, the present study will be able to evaluate the impact of policies relating to independent variables on various income segments in Egypt's economy.

From this perspective, the rationale of the present paper concentrates on revisiting the limited literature on factors that derive economic growth in Egypt. Moreover, the objective is to raise discussions with the previous literature on this topic on several points of the analysis. Therefore, the analysis must be enriched by answering a variety of questions. For example, regarding the contributions of productivity, capital, HC, and labor are they the same for all stages of economic growth? Do different income levels in the Egyptian economy have different contributions? What is the impact of these factors on different income segmentations in the Egyptian economy? Of course, the standard OLS regression methodology could not provide answers to these questions. Therefore, the present paper applies the QR methodology to answer them. The remainder of the paper is structured as follows. Section 2 presents the literature, and Section 3 provides the methodology used. Section 4 summarizes the main empirical findings, and Section 5 draws conclusions and proposes several policy recommendations.

2. Literature review

Surveying the literature, we can consider the works of Mankiw, Romer [7], and Young [8] to be the pioneer papers investigating the sources of economic growth and explain international variations in growth and income. However, Solow [9] sparked a debate about the causes of economic growth, which was largely heated by the East Asian countries' phenomenal growth. In relation to this debate, the main drivers of economic growth have been the subject of discussion and in-depth economic analysis. Furthermore, through cross-sectional analytical studies, extensive comparisons have been made among regions to investigate differences and similarities in the share of productivity and factor accumulation in economic growth.

Barro [10] followed the same path and investigated economic growth and its determinants in a panel of 100 countries from 1960 to 1990. The empirical analysis in this cross-sectional study approved that under the case of a given initial real per capita GDP, economic growth can be improved through improvements in some economic and human capital variables. From this perspective, reduced government consumption and inflation rates, lower fertility, increased schooling and life expectancy, more effective rule of law, and improvements in the trade balance are all considered incentives for economic growth.

Indeed, the overwhelming majority of the literature on economic growth is derived from cross-country analytical studies [7,8,10–16]. This type of research allows for comparisons between several nations and regions over different time periods to infer the economic growth process. However, using the findings of these cross-country studies to validate them in a specific country is inaccurate. Therefore, studying a specific country in economic analysis and statistical estimations is critical, by focusing on discussing and analyzing its growth process over time and clarifying the factors with the most profound impact on its economic growth path.

For Egypt, Kheir-El-Din and Moursi [1] were the first researchers who examined Egypt's economic growth path from 1960 to 1998. A system of equations was used to estimate the coefficients of total factor productivity (TFP) and the aggregate production function in their study. Moreover, they used the Kalman filter algorithm to make their estimate [17]. They gave a comprehensive presentation that examined aggregate growth accounting and the role of technological progress and fiscal factors of production in Egypt's economic growth. They also used the TFP estimates to describe the structural pattern of economic growth in detail. Moreover, they conducted regression analysis to test the relationship between a group of policy-related macroeconomic variables as independent variables and technological progress as dependent variable. As a result, they arrive at a set of key conclusions, which can be summarized as follows.

First, capital accumulation can be considered the primary driver of economic growth in Egypt from 1960 to the end of the 1980s. Second, since the Egyptian government launched its ERSAP in 1991, aggregate investment has decreased, thus reducing capital accumulation's contribution to economic growth. Meanwhile, TFP increased its contribution to economic growth. Third, they found an inverse relationship between TFP and capital accumulation in the formulation of economic growth in Egypt. Fourth, they concluded that capital growth is the primary cause of real output fluctuations in the Egyptian economy, which they attribute to the fact that labor growth was constant during this period. Fifth, from 1991 to the end of the 1990s, TFP had the largest share of the contribution to economic growth, accounting for 44%. Consequently, they claimed that the increase in TFP contribution resulted from crowding out the contribution of capital accumulation, which had significantly decreased.

Finally, they concluded that capital accumulation in the Egyptian economy is insufficient to achieve sustainable and efficient economic growth. The authors attributed this conclusion to the aforementioned five results and the diminishing returns to capital demonstrated by the production function. Moreover, these findings reveal that adding more investment and capital to the Egyptian economy does not guarantee increased economic growth. Furthermore, the authors continued their conclusions on this line of economic thought, stating that Egypt's economy is most probably in recession because it has exceeded the capital labor ratio threshold. Furthermore, they asserted that the TFP contribution is the primary driver of Egyptian economy's sustainable high growth. They backed up this last point by claiming that lowering capital intensity has no effect on Egypt's economic efficiency. They also argued that the main obstacles for Egypt's economic growth are misallocation of capital stock and management failure.

For the 1973–2002 period, Kamaly [2] presented a comprehensive analysis of Egypt's economic growth sources. During the study period, the author used the growth accounting technique to clarify the sources of economic growth in Egypt. He concluded that changes in productivity and accumulating factors of production are the driving forces behind Egypt's economic growth. According to this viewpoint, the author attributed Egypt's strong economic growth after the 1973 war to high productivity and capital accumulation growth. However, the slow economic growth witnessed during the 1980s may have been caused by a decline in both capital accumulation and productivity growth.

The author continued, even after instituting ERSAP in 1991, capital accumulation growth has continued to decline, showing a persistent downward trend for the 1990s. As a result, the contribution of capital in economic growth in Egypt has lowered to become closer to labor contribution. However, productivity has enhanced clearly during the 1990s as a result for applying the privatization program and the expansion of the private sector in the Egyptian economy.

Following Kamaly (2006) and Pelinescu [18], this study uses the economy-wide production function, which includes a measure for labor skills. On this production function, the assumption of constant returns to scale will also be relaxed. Therefore, the factor input weights must be estimated. Consequently, two methods can be used for estimating these weights. The first method is to use national accounts data, provided that these data are fully accessible. The second method is to use econometric estimations based on GDP and factor input data [7,11,19–24]. However, as previously stated, the current study will incorporate human capital into the analysis of growth accounting to become underpinned by the augmented Solow production function.

Furthermore, we must discuss the impact of savings and population growth rates on both human capital and economic growth in the analysis, as is the case in several recent papers [25–27]. In early literature, such as Hall and Jones [14], the share of physical capital in output was estimated to be 1/3. To estimate this share, they used national accounts data for some developed countries. Moreover, they used this estimated share as a benchmark for capital share for all other countries, based on the false assumption that technology is the same in developed and developing countries. However, studies that estimated different production functions for countries that differ in income level found that technology is also different. As a result, differences in technological progress from one country to another create differences in factors of production shares.

Indeed, following the recent literature [16,28–36], the present study differentiates between Egypt and other developed and rich countries, where the production function is estimated, especially for the Egyptian case.

Thus, the current study has a high priority of contributing to the literature on Egyptian economic growth by estimating the shares of factors of production rather than using estimates for developed countries or even estimates from cross-country papers.

Considering this economic theory, the present study contends that applying constant returns to scale (CRS) to the estimated Egyptian production function is inappropriate. Furthermore, the assumption that capital is a homogeneous unit is illogical. Therefore, the present study will take the same approach as that of Brandt, Schreyer [37], Bakker, Crafts [38], and Inklaar, Albarrán [35]. That is, "different types of capital assets have different marginal products" and thus have different effects on economic growth over time. Furthermore, the current research will construct a series of capital inputs that account for the development of human and fiscal capital and their impact on productivity changes in Egypt. Following Chen [39] and Freeman, Inklaar [36], we included intangible assets and subsoil assets in estimating capital input for Egypt to avoid underestimating physical capital and its role in growth variation.

Summary for the main Literature

Author	Variables Considered	Countries Considered	Model Employed
Solow [9]	Productivity, Labor and Capital	Group of countries	Econometric Estimations
of Mankiw, Romer [7]	Productivity, Labor, Human Capital and Capital	Group of countries	Econometric Estimations
Barro [10]	Productivity, Labor, and Capital	100 countries	Econometric Estimations
Hall and Jones [14]	Productivity, Labor, and Capital	Group of Developed Countries	National Accounts Data
Caselli (2005)	Productivity, Labor, Human Capital and Capital	Group of countries	Econometric Estimations
Inklaar, Albarrán [35]	Productivity, Labor, Human Capital and Capital	All Countries	Econometric Estimations
Freeman, Inklaar [36]	Productivity, Labor, Human Capital and Capital	Group of Countries	Econometric Estimations
Kheir-El-Din and Moursi [1]	Productivity, Labor, and Capital	Egypt	A System of Equations
Kamaly (2006)	Productivity, Labor, and Capital	Egypt	Econometric Estimations

Ultimately, the economic growth factors have been approached from various theoretical perspectives. The conclusions were solely based on the assumptions made during the development of the theoretical model. However, the hypotheses remain to be debated and agreed upon. Furthermore, there is a scarcity of research on Egypt's economic growth sources. Accordingly, to the best of our knowledge, this is the first study to contribute to the literature by covering the period from 1991 to 2020 and analyzing Egyptian economic growth using the econometric technique known as QR. The data used and the empirical methodology employed are discussed next.

3. Methodology and data

3.1. Data collection and transformation

The present study uses the data available in the latest version of Penn World Table (version 10.0) published in February 2021. Data for the following variables are available for Egypt during the 1991–2019 period: *employment*, *population*, *real GDP*, *the share of labor income in GDP*, *hours worked*, *real internal rate of return*, *average depreciation rate*, *human capital index*, and *average hours worked*.

In terms of capital input, the present study not only uses capital stocks to measure capital input, but also uses *capital services*, which are obtained from the Egyptian National Accounts data. Consequently, *residential buildings*, *other structures*, *information technology*, *communication technology*, *other machinery*, *transport equipment*, software, *other intellectual property products*, and *cultivated assets* are used to construct *capital services* data (PWT10.0, 2021; [35].

Moreover, unlike the two previous studies of Kheir-El-Din and Moursi [1] and Kamaly (2006), the present study includes intangible and subsoil assets in constructing a capital input series for Egypt. Additionally, following Jorgenson and Nishimizu [40] and Mankiw et al. (1992), this study investigates the effects of *human capital*, *capital services,* and *productivity* on *economic growth*. Additionally, the study performs some estimates to end up with *aggregate supply of investment* by adding production to the net exports. Furthermore, this study's variables are all expressed in natural logarithmic form.

3.2. Empirical framework

3.2.1. Production function and growth accounting

Following Mankiw, Romer [7], Caselli [12], we started growth accounting by the aggregate production function on the following form:

$$\mathrm{Y} = \mathrm{A\ f\ (K, L)} = K^{\alpha} H^{\beta} (\mathrm{A\ L})^{1-\alpha-\beta} \tag{1}$$

Therefore, a Cobb-Douglas production function is assumed where the output (Y) is produced using capital (K), human capital (H), labor (L), and technology level (A). Consequently, the present paper has to follow Mankiw, Romer [7], Caselli (2005), Hsieh and Klenow [41], Feenstra, Inklaar [33], Inklaar and Diewert [34], and Inklaar, Albarrán [35] to include these four variables in its model. However, we will adjust equation (1) by including human capital in the equation as a factor of production. In addition, each factor of production has its own elasticity coefficient, as shown in equation (2). Furthermore, we will not follow Mankiw, Romer [7] assumption of CRS in the production function, as evidenced by the two coefficients (α and 1–α). Consequently, this paper will keep the calculation of the coefficients (θ, β, α, δ) up to the real data and econometric estimations.

$$\mathrm{Y} = \mathrm{A\ f\ (K, L)} = \mathrm{A}^{\theta} K^{\beta}\, L^{\alpha} H^{\alpha} \tag{2}$$

where Y is the country's GDP produced using the production function with four inputs of production: capital K, TFP A, human capital H, and the number of employment L. In equation (2), there is no assumption concerning returns to scale in the Cobb–Douglas production function. Therefore, a country's GDP per capita can be derived by dividing equation (2) by country's population. Hsieh and Klenow [41] outlined a method for accounting for the differences in GDP per capita levels across countries to answer the following question: What would be the increase in GDP per capita if productivity or one of the factor inputs increased, holding other two factors of production constant? Apparently, this is an acceptable hypothesis to investigate the growth path in a single specified country under the assumption that the economy lies on the same point of steady state.

Therefore, following our assumption on returns to scale and Mankiw, Romer [7], we employ the coefficients (θ, β, α, δ) for the relative importance of every input in analyzing economic growth.

In addition, we can re-estimate equation (2) by taking a log and differentiating with respect to time for each term of the equation, thereby yielding the following equation:

$$\frac{\dot{\mathrm{Y}}}{Y} = \frac{\dot{A}}{A} + \beta \frac{\check{\mathrm{K}}}{\mathrm{K}} + \frac{\dot{\mathrm{H}}}{H} + \alpha\ \frac{\dot{\mathrm{N}}}{N} \tag{3}$$

In equation (3), the dot (.) over the variable represents this variable's rate of change with respect to time. Similarly, α and β have no restrictions since the paper is not assuming CRS, but rather letting these two parameters take any values up to the data.

In equation (3), $\frac{\dot{\mathrm{Y}}}{Y}$ denotes the change in output, which is attributed to change in capital $\frac{\check{\mathrm{K}}}{\mathrm{K}}$, change in the amount of labor $\frac{\dot{\mathrm{N}}}{N}$, change in human capital $\frac{\dot{\mathrm{H}}}{H}$, and change in productivity (TFP) $\frac{\dot{A}}{A}$.

3.2.2. Estimating productivity

Unlike other cross-country studies, this study will not assume that all types of capital and labor inputs contribute equally to economic growth. As a result, a more flexible production function must express variations in the share of factor inputs. From this perspective, this study follows Jorgenson and Nishimizu [40], Mankiw, Romer [7], Schreyer [42], Feenstra, Inklaar [33], Inklaar and Diewert [34], and Inklaar, Albarrán [35] to assume a *trans*-log production function;

$$\log(\mathrm{Qm}) = \alpha\mathrm{m}(\log\mathrm{Km}\text{–}\log\ \mathrm{K}) + (1-\alpha\mathrm{m})(\log\mathrm{Lm}\text{–}\log\ \mathrm{L}) \tag{4}$$

where Qm, in equation (4), is the level of factor inputs in a country m, αm is the average of the capital income share in country m, log Km is the capital input level in a country m, log K is the cross-country average of capital input level. log Lm is the labor input level in a country m, and log L is the cross-country average of labor input level. Additionally, the labor input is expressed by multiplying total hours worked *Hm* by a human capital index *hm*, which depends on the average years of schooling and the schooling rate of return [12, 20].

3.2.3. Estimating capital

One of the main contributions of the present study is estimating the share of capital input in economic growth based on different capital assets. Consequently, the capital input Ki and rental prices ri for multiple capital assets i = 1,2,3, …., I, must be estimate. As discussed by Jorgenson and Nishmizu (1978), the capital manual of OECD (2009), andm recently, by Inklaar, Albarrán [35], the asset rental price at time t can be estimated using equation (5):

$$ri,t = P^N i,t-1\ it + P^N i,t\ \delta i - P^N i,t-1\ \left(P^N i,t - P^N i,t-1\right) \tag{5}$$

where it is the required rate of return on capital, $P^N i$ is the purchase price of asset i, and $\delta i =$ is the geometric depreciation rate.

- ***Capital Services instead of Capital Stock***

Unlike the growth analysis in Kheir-El-Din and Morsi (2006) and Kamaly (2006) that depends on estimates for capital stock, the present study depends on estimates for capital services. According to OECD (2001), capital services are considered the most appropriate measurement for capital in analyzing growth accounting and productivity. This study aims to avoid underestimating the role of physical capital in development accounting, which has been supported by recent studies [31,35,36,39,43]. These recent research papers demonstrated that the problem of underestimation is due to the use of capital stock, which undervalues the weight of short-lived assets compared to capital service methodology.

From this perspective, the contribution of capital to output growth is calculated by multiplying capital services' growth rate by the profit share. As a result, calculating capital services is a critical component of TFP measurement. Therefore, one of the study's main contributions is to develop capital services estimates for the Egyptian economy and use these estimates instead of capital stock.

4. Empirical analyses

4.1. Summary statistics and correlations

Table 1 provides a brief descriptive analysis and the correlations for this model. The descriptive analysis demonstrates the distribution properties of the individual variables, while the correlation matrix indicates the relationship between these variables in our proposed model.

Table 1 presents the descriptive statistics as well as the correlation matrix of the data used in the study after logarithmic

Table 1
Summary statistics and correlations.

	Ln Y	Ln A	Ln K	Ln L	Ln H
Mean	13.466	−0.577	13.384	9.845	0.767
Median	13.446	−0.524	13.381	9.825	0.766
Maximum	14.068	−0.0367	14.415	10.165	0.985
Minimum	12.834	−0.926	11.756	9.470	0.541
Std. Dev	0.368	0.233	0.806	0.218	0.139
Skewness	−0.087	0.234	−0.368	−0.094	−0.007
Kurtosis	−1.270	−0.319	−1.042	−1.355	−1.337
Shapiro–Francia W test for normality	5.671	6.416	5.323	5.711	6.493
Probability	0.00001	0.00001	0.00001	0.00001	0.00001
Shapiro–Wilk W test for normality	6.135	6.967	5.755	6.135	7.043
Probability	0.00000	0.00000	0.00000	0.00000	0.00000
Skewness/Kurtosis tests for normality	23.86	55.69	24.50	12.28	55.91
Probability	0.00000	0.00000	0.00000	0.0022	0.0000
Obs.	29	29	29	29	29
Ln Y	1.000				
Ln A	0.3272[a]	1.000			
Ln K	0.9922[a]	0.2805[a]	1.000		
Ln L	−0.9601[a]	0.5745[a]	0.9351[a]	1.000	
Ln H	0.4705[a]	0.9848[a]	0.4191[a]	0.6974[a]	1.000

Variable definition: Ln Y, Ln A, Ln K, Ln L, and Ln H is the logarithmic form of output, productivity, capital, labor, and human capital in Egypt, respectively.
[a] Denotes significance at a 95% confidence level.
Source: Authors' calculations using STATA 13.

transformations. As can be seen in Table 1, the measures of the probabilities of Shapiro–Francia W, Shapiro–Wilk W, and Skewness/Kurtosis tests for normality indicate that the five variables do not follow a normal distribution. Additionally, we can conclude that there is a strong positive and statistically significant relationship between Ln A, Ln K, and Ln H and Ln Y. However, there is a strong negative and statistically significant relationship between Ln Y and Ln L. Clearly, four of the correlation signs are consistent with economic theory. The correlation sign for labor is negative, which will be analyzed later. Consequently, the nonnormality of the five variables gives significant evidence that the quantile regression (QR) technique should be applied to estimate the model.

4.2. Estimates for ordinary least squares (OLS) regression

By estimating Equation (3), estimates were obtained for the coefficients of the aggregate production function using both ordinary least squares (OLS) and QR regressions. The econometric analysis is conducted using R4.0.5 and R-Studio statistical programming and computing packages.

According to the results expressed in Tables 1 and 2, this paper investigates several important findings.

First, the residual standard error is found to be 0.03251 on 25° of freedom. Also, the F-statistic is 229.4 on 3 and 25 DF and p-value: <2.2e-16. Moreover, the Multiple R-squared is 0.9649 and the Adjusted R-squared is 0.9607, which means that the estimation for this OLS regression is highly significant. In addition, the estimated coefficients that correspond to each variable are all significant according to their t-values and Pr (>|t|).

Second, a very vital finding appeared in the four estimated coefficients of the variables productivity, capital, human capital (HC), and labor, which are 0.52, 0.23, 0.15, and −0.998 respectively. Of course, the surprise of these coefficients is the negative coefficient of Labor in both Tables 1 and 2 This means that the contribution of labor to Egypt's economic growth is negative where the addition of labor by 1% in the Egyptian economy lowers economic growth by 0.998%. This finding can be verified by the fact that the Egyptian Public Administrative Agency employed about 6.78 million people in 2019 (6 million in the government and 0.78 million in public enterprises) according to the Egyptian Central Agency for Public Mobilization and Statistics (2020).

Of course, the Egyptian Public Administrative Agency is considered the biggest public sector in the world with a rate of one employee for every 14 citizens, while the international rate is one employee for every 40 citizens. It is noted that the Egypt's public sector is filled with disguised employment, which reduces its contribution to the economic growth process.

Regarding the private sector, it seems that the Egyptian labor force lacks the updated, modern, and advanced knowledge, which can be attributed to the noticeable deterioration in education at all levels in Egypt. This lack of knowledge and updated techniques of production in addition to inefficient public sector cooperation together that causes the negative contribution of labor in economic growth in Egypt. This finding is also evidenced by the fact that per capita (GDP) in Egypt was 3019.2 USD in 2019 for the Egyptian population of more than 100 million citizens, while the per capita GDP in Israel was 43,592.08 USD in 2019 with a population of only 9 million (World Bank, 2021).

The per capita income in Israel is more than 14 fold the value in Egypt. In other words, it seems that the input of labor is used beyond its optimum level in the Egyptian economy; therefore, it is contribution is bound to fall and becomes negative. Consequently, it gives evidence in support of disguised unemployment status in Egypt's public sector. In addition, because of the strong correlation between the persistent increase of population and number of employed in Egypt; therefore, the ratios GDP/Pop and GDP/Labor can be expected to fall leading to a negative contribution of labor to economic growth in Egypt.

Third, the present study estimates the capital coefficient to be 0.23, which is the lowest estimation of capital contribution in Egypt's economic growth among all studies conducted of the Egyptian economy. In Kamaly (2006), this estimate is 0.53, in Kheir-El-Din and Morsi (2006), it is 0.65, while in Senhadji [16], it is 0.57. The present study attributes these differences to several factors. The first factor appears in the data used for the variable. Whereas previous studies used data for capital stock, the present study uses data for capital services. According to recent studies [31,35,36,39,43], the methodology of capital services gives higher weight to short-lived assets.

Fourth, the HC coefficient is estimated at 0.15, which is positive and reflects the enhancement of HC's role in economic growth in Egypt over the period of study. It is noted that the Egypt's HC witnessed crucial improvements during the last three decades in the variety of knowledge and capabilities that the Egyptian graduates acquired, especially in the fields of information technology, language, engineering, tourism, and financial services. Consequently, Egypt, as all low-income countries, invests less in short-lived assets. Of course, this has a negative impact on the contribution of capital to the economic growth process. The second factor can easily be

Table 2
OLS regression estimates.

Variable	Estimate	Std. Error	t-value	Pr (>|t|)
Intercept	11.43	0.65967	17.335	1.91e-15 ***
Productivity	0.52	0.13756	3.781	0.000867 ***
Capital	0.23	0.07676	3.021	0.005740 **
Human Capital (HC)	0.15	0.08416	2.562	0.003250 **
Labor	−0.998	0.11770	−8.485	7.90e-09 ***

***, **, and * denote significance at 99%, 95%, and 90% confidence levels, respectively.
All variables used in this study are expressed in the natural logarithmic form.
Source: Authors' calculations.

Table 3
Quantile regression (QR) estimates for quantiles 0.1 through 0.9

Variables	Quantile 0.1		
	coefficients	lower bd	upper bd
Intercept	11.50135	5.93986	12.44044
Productivity	0.27648	0.19809	1.40340
Capital	0.30316	−0.24407	0.36514
Labor	−1.03832	−1.15608	−0.02805
Human Capital	0.15106	−0.06810	0.23221
Variables	Quantile 0.2		
	coefficients	lower bd	upper bd
Intercept	11.32,562	9.38372	11.57198
Productivity	0.31097	0.21067	1.28591
Capital	0.32414	0.02537	0.35305
Labor	−1.00865	−1.05650	−0.54923
Human Capital	0.16106	−0.05810	0.24221
Variables	Quantile 0.3		
	coefficients	lower bd	upper bd
Intercept	11.18469	9.80835	12.48841
Productivity	0.48266	0.22,874	1.03040
Capital	0.22493	0.15054	0.38860
Labor	−0.95783	−1.22780	−0.67860
Human Capital	0.08106	−0.08810	0.13221
Variables	Quantile 0.4		
	coefficients	lower bd	upper bd
Intercept	11.56065	10.39102	12.17690
Productivity	0.52028	0.37171	0.71350
Capital	0.22046	0.13376	0.49645
Labor	−1.01940	−1.14619	−0.78107
Human Capital	0.08002	−0.08915	0.13020
Variables	Quantile 0.5		
	coefficients	lower bd	upper bd
Intercept	11.78985	10.61707	13.17202
Productivity	0.55432	0.45600	0.82202
Capital	0.18106	0.06810	0.33221
Labor	−1.05084	−1.30232	−0.84459
Human Capital	0.06106	−0.01810	0.11221
Variables	Quantile 0.6		
	coefficients	lower bd	upper bd
Intercept	12.09397	10.54324	13.17385
Productivity	0.57084	0.37860	0.79227
Capital	0.15017	0.09291	0.31216
Labor	−1.09771	−1.28934	−0.81630
Human Capital	0.05106	0.00990	0.09221
Variables	Quantile 0.7		
	coefficients	lower bd	upper bd
Intercept	12.32059	9.62606	13.95786
Productivity	0.54590	0.36256	0.71023
Capital	0.20422	0.06380	0.39743
Labor	−1.14580	−1.38072	−0.74511
Human Capital	0.07106	0.02725	0.13881
Variables	Quantile 0.8		
	coefficients	lower bd	upper bd
Intercept	13.23335	9.39423	14.80174
Productivity	0.60524	0.41471	0.74945
Capital	0.09128	0.06800	0.39754
Labor	−1.28304	−1.54693	−0.65243
Human Capital	0.03276	−0.09875	0.07541

(*continued on next page*)

Table 3 (*continued*)

Variables	Quantile 0.1		
	coefficients	lower bd	upper bd
Variables	Quantile 0.9		
	coefficients	lower bd	upper bd
Intercept	14.19425	6.74947	14.56044
Productivity	0.50159	0.36804	0.70701
Capital	0.10171	−0.15906	0.65194
Labor	−1.45636	−1.52602	−0.37962
Human Capital	0.04206	−0.06794	0.08359

All variables used in this study are expressed in the natural logarithmic form.
Source: Authors' calculations using R 4.0.5.

noted in the sample data used in the previous studies where it was applied for the period from 1960 to 2002. However, the present study uses an updated data sample for the period from 1991 to 2019 as explained previously. It can be observed between 1960 and 2002, the Egyptian government invested heavily in public education and health sectors, infrastructure, and national industry; therefore, the impact of capital stock on economic growth reached its peak. On the other hand, between 1991 and 2019, a severe deterioration in investment in all these sectors can be noticed, which appeared clearly in the degradation of the public education, health, infrastructure, and transportation sectors. As a result, a logical outcome appeared in the reduction of capital contributions to economic growth in Egypt between 1991 and 2019.

Fifth, the highest contribution of an input factor in Egypt's economic growth is the contribution of total factor productivity (TFP) with a coefficient of 0.52. This important finding is closer to the estimate by Kheir-El-Din and Morsi (2006), who proved that TFP was the highest contributor to economic growth in Egypt between 1990 and 1998 with a coefficient of 0.44. Of course, this finding seems logical according to the great improvements that happened in the levels of technological progress and HC in Egypt between 1991 and 2019.

4.3 Despite these very important findings, this analysis must be enriched by answering several questions. For example, are the contributions of productivity, capital, HC, and labor constant from the early stages of economic growth to the advanced stages? Do these contributions differ among different income segments in the Egyptian economy? Do factors other than these three input factors have the same impact on economic growth in Egypt through all stages of the growth process? What is the effect of these factors (other than these three input factors) on different income classes in the Egyptian economy? Of course, the standard OLS regression methodology and analysis used previously, with its one-size-fits-all assumptions about the relationship between economic and income growth on the dependent side and different input factors of production on the independent side, could not provide answers to these questions. Therefore, the present study applies the QR methodology, as presented in Table 3, to answer these crucial questions.

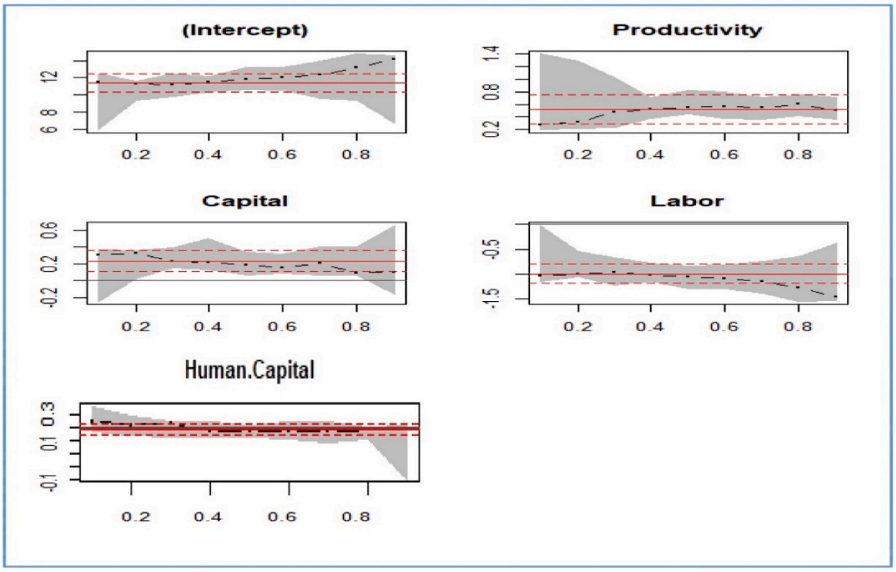

Fig. 1. Graphical illustration of OLS and QR models.

4.2.1. Estimates for quantile regression (QR)

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The OLS and QR models for economic growth and the four input factors in Egypt are illustrated graphically in Fig. 1.

Noting that the OLS regression is illustrated in three straight red lines while the QR is the shadow in gray in the same figure. Therefore, a comparison can easily be made between the two regression methodologies.

The coefficient of productivity is increasing according to the increase in quantiles. Therefore, productivity has clearly had a large impact on the higher stages of economic growth. In other words, productivity has less impact on the income growth of those with a low-level income than those with a high-level income in the Egyptian economy. Therefore, productivity's contribution to economic growth is not constant for all income segments in Egypt nor all stages of economic growth. In addition, in the early stages of economic reform during the 1990s, productivity increased slowly and the contribution of productivity to the economic growth formulation was less than during the following two decades of the third millennium. This can be attributed to the noticed enhancement of technological progress over the last two decades in the Egyptian economy. Of course, improvements in the use of technology increased productivity, especially for the high-income segments of Egyptian society, which are characterized by higher levels of education.

Capital goes in the opposite direction of productivity. It can be noted that the coefficient of capital is decreasing as the quantiles increase. Consequently, additional capital has a large impact on the early stages of economic growth. As a result, an increase in capital caused economic growth to expand at the start of the economic reform program and during the 1990s. However, the contribution of additional capital investment to economic growth deteriorated over the following two decades.

HC goes in the same direction as capital—its coefficient declines as the quantiles increase. This means that the improvement in HC has a higher impact at the start of the economic reform process. In addition, investment in HC benefits lower income groups in the Egyptian economy more than higher income groups. Therefore, the higher the expenditure on HC (such as investing in schools, universities, research and development, and public health), the better the distributional effects toward lower income groups and the middle class in the Egyptian economy. Moreover, it indicates that more investment in HC will lead to higher income for lower income groups and more convergence between lower and higher income groups in Egyptian society.

The contribution of labor to economic growth is decreasing across the quantiles of labor. As we move from lower quantiles to higher quantiles, the share of labor in economic growth is deteriorating. Moreover, in all quantiles, the contribution of labor is negative, reflecting the expansion of TFP. Therefore, HC's contribution to Egypt's economic growth has happened at the expense of the contribution of labor and capital during this era.

Based on the data for Egypt in (PWT) version 10.0 and using Equation (6), Tables 4 and 5 present the contribution of factors of production including TFP and HC. In Table 4, the contribution is calculated for each period in absolute terms. Between 1991 and 2000 (first generation), the Egyptian economy grew by 49.5%. Consequently, this growth was driven by 34.3% growth in capital, 4.4% growth in TFP, 15.5% growth in HC, and 27.9% growth in labor.

In Table 4, the contribution of capital had the lion's share during the first period (1991–2000). However, the situation changed in the second and third periods, during which the contribution of labor had the lion's share, followed by HC. Therefore, the importance of HC's contribution to economic growth has increased rapidly during the periods of this analysis. The crucial decline in the contribution of capital over the years is consistent with the moribund trend of capital growth shown by this paper and previous studies.

In addition, the contribution of labor through the three periods of study was declining as a simulation to the attitude of capital which reflects the limited value added of labor to economic growth in Egypt that the paper raised previously. Since 1991, the increased importance of and dependence on the private sector as a result of the ERSAP and following economic reforms led to the improvement of the contributions of HC and TFP, which reflects the increase in productivity and efficiency in employing factors of production in the Egyptian economy. The contribution of labor is negative throughout all four generations. However, it increases from −27.9% in the first generation to −16.1% in the fourth generation, while there are noted increases in the contribution of HC and TFP, which reflects the shift toward efficient labor instead of traditional labor.

In Table 5, the contribution of every factors of production is taken to be relative to the total economic growth to understand the importance of each factor of production in Egypt's economic growth. In addition, the summation of these contributions provides the accurate returns to scale in the Egyptian economy, noting that the paper is not assuming constant returns to scale (CRS). Moreover, the paper investigates the status for returns to scale in the Egyptian economy for the three periods of analysis. During 1991–2000, returns to scale were 0.93 [i.e., decreasing returns to scale (DRS)]; during 2001–2010, returns to scale were 0.97 (i.e., DRS), for 2011 to 2019, the returns to scale were 1.07 (i.e., increasing returns to scale (IRS)). Consequently, these findings assure this paper's refusal to assume

Table 4
Contribution of factors of production to economic growth in Egypt between 1991 and 2019 (figures are %).

Period	Total GDP Growth	Contribution of Labor	Contribution of Capital	Contribution of TFP	Contribution of HC
1991 to 2000 **First Generation of Reform**	49.5	−27.9	34.3	4.4	15.5
2001 to 2010 **Second and Third Generations of Reform**	49.4	−29.6	27	6	21.7
2011 to 2019 **Fourth Generation of Reform**	37.9	−16.1	8.3	6.6	12.9

Source: Authors' calculations

Table 5
Shares of the factors of production in economic growth in Egypt between 1991 and 2019 (figures are %).

Period	Total GDP Growth	Share of Labor	Share of Capital	Share of TFP	Share of HC	Summation of Shares	Returns to Scale
1991 to 2000 **First Generation of Reform**	49.5	−56.3	69.3	8.9	31.2	53.2	0.93
2001 to 2010 **Second and Third Generations of Reform**	49.4	−60.0	54.8	12.2	43.9	50.9	0.97
2011 to 2019 **Fourth Generation of Reform**	37.9	−49.1	25.2	20.1	39.1	35.3	1.07

Source: Authors' calculations.

CRS as in the previous literature such as Kheir-El-Din and Morsi (2006).

With regard to output, savings, and population growth, Tables 4 and 5 and Figs. 2, 9 and 10 show the following. There exists a trend of decline from 49.5% to 49.4% and finally to 37.9% for the three periods of study, respectively. Moreover, output growth in the Egyptian economy exceeded 73% between 1981 and 1990 ((PWT) version 10.0 and authors' calculations). Consequently, it can be concluded that Egypt's economic growth has sharply deteriorated over the last four decades. In addition, the decline of economic growth through the first generation, because of external and internal shocks, is accompanied by a sharp decline in the gross savings rate as a percentage of GDP, which declined from around 35% in 1991 to 17.6% in 2000 (World Bank, 2022). However, population growth rate experienced a small decline from 2.27% in 1991 to 1.93% in 2000 (World Bank, 2022).

Then, output growth started to rise again through the second and third generations due to economic liberalization policies, free trade, expanding private sector participation, legal and institutional reforms, improvements in tourism, and increasing FDI. Consequently, 2001 to 2010 witnessed a clear jump in economic growth from 3.5% in 2001 which doubled to 7.2% in 2008. This growth improvement resulted from the enhancement of trade, exports, and FDI, which is consistent with similar experiences in other emerging markets such as Hobbs, Paparas [44].

This growth jump was accompanied by a parallel jump in the gross savings rate as a percentage of GDP from 17.5% in 2000 to 23.6% in 2008. Moreover, there was a consistent decline in the population growth rate, which decreased from 1.93% in 2000 to 1.78% in 2008. Also, this era showed an increase in HC and TFP contribution and share in economic growth. Therefore, a rise in savings accompanied by a decline in the population growth rate is required to boost economic growth in the Egyptian economy. These findings are consistent with Mankiw, Romer [7], who found that a higher savings rate raises TFP, leads to higher economic growth and per capita income, which in turn leads to a higher level of HC. In addition, they concluded that higher population growth in the augmented Solow model lowers income and capital and that HC must be spread more thinly over the population of workers, which in turn leads to lower TFP. Of course, the opposite is also true, which can be seen in Egypt's economic growth formulation in this era.

Consequently, during the fourth generation (i.e., from 2011 to 2019), the savings rate sharply dropped from 23.6% in 2008 to reach 9.6% in 2015 that was accompanied by weak and volatile economic growth rates varied from 1.7% in 2011 to 2.9% in 2014 and reached 5.6% in 2019 due to an increase in public investment and infrastructure reform. Also, this era showed a rapid increase in the population growth rate from 1.86% in 2009 to 2.26% in 2014 and continued at around 2% between 2018 and 2019. This period of growth has been negatively impacted by the political instability that emerged from two revolutions. Also, these findings led to a sharp decline in the contribution of HC to economic growth, which is consistent with Mankiw, Romer [7].

Considering the law of diminishing returns to inputs, Kheir-El-Din and Morsi (2006) concluded that this deterioration in economic growth could be explained by the Egyptian economy exceeding its capital-labor ratio efficient threshold. As a result, accumulating more capital is not always conducive to growth. However, the current study is totally refuting this conclusion according to several arguments.

First, applying the law of diminishing returns to capital is considered correct if and only if other inputs are held constant. However, this is not the case in the Egyptian economy since other factors of production, such as TFP and HC, were increasing over time as shown in Tables 4 and 5 and Figs. 4 and 7. The same situation appeared for other factors of production in Figs. 5 and 6. Second and most importantly, Fig. 2 shows that the capital growth ratio has been decreasing rapidly over the three periods from 34.3% to 27% and

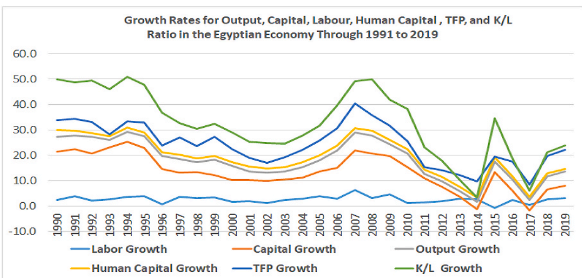

Fig. 2. Growth rates for output, capital, labour, human capital, TFP, and K/L ratio in the egyptian economy through 1991 to 2019.

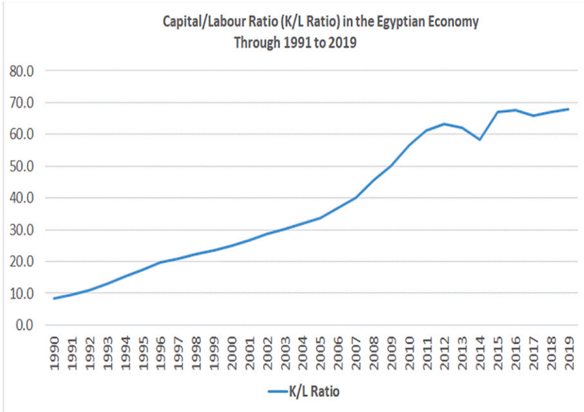

Fig. 3. Capital/labour ratio (K/L ratio) in the egyptian economy through 1991 to 2019.

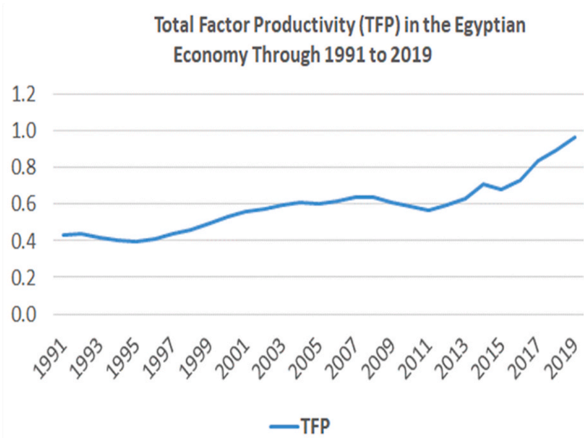

Fig. 4. Total factor productivity (TFP) in the egyptian economy through 1991 to 2019.

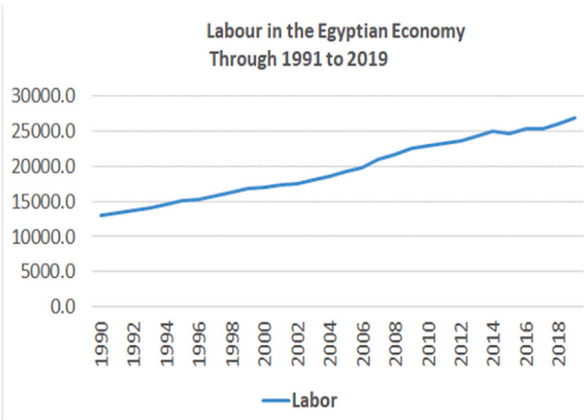

Fig. 5. Labur in the egyptian economy through 1991 to 2019.

finally to 8.3%, which is very low. Also, Figs. 3, 5, 6, 8 and 10 show that output and the capital-labor ratio are increasing although the savings rate is declining. This means that capital accumulation was superior to labor accumulation, which led to an increase in both output and the capital-labor ratio. In other words, the economy needs more capital accumulation that exceeds labor accumulation to grow. Therefore, this noticed decline in economic growth in Egypt may be attributed to a lack of capital accumulation, which was caused by a sharp decline in savings.

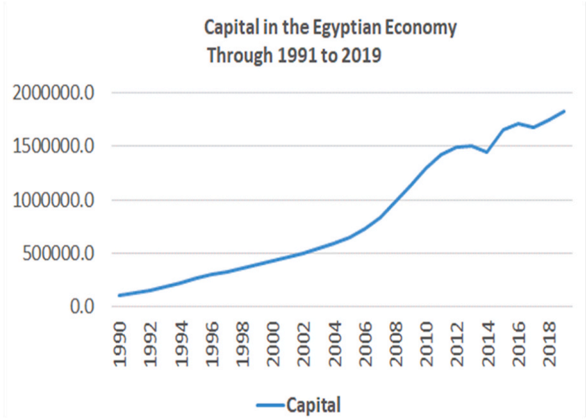

Fig. 6. Capital in the egyptian economy through 1991 to 2019.

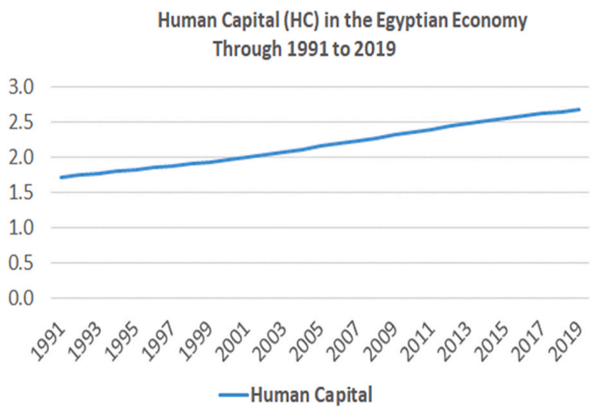

Fig. 7. Human capital (HC) in the egyptian economy through 1991 to 2019.

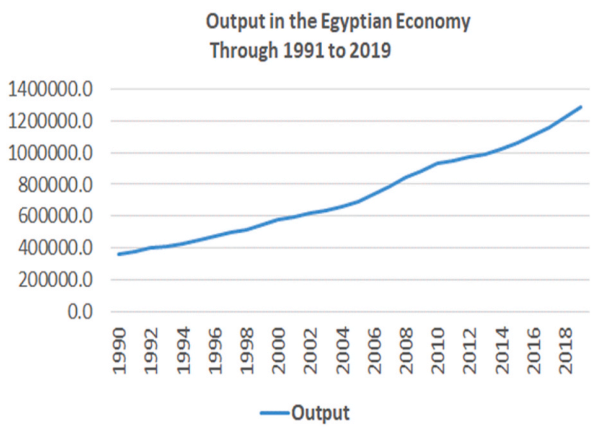

Fig. 8. Output in the egyptian economy through 1991 to 2019.

5. Conclusion

This paper analyzes the economic growth of Egypt over four generations of reform that were implemented between 1991 and 2019. I have suggested that variations in Egypt's economic growth are best analyzed and investigated using an augmented Solow growth model. According to this model, the production function includes the stock of HC in addition to the traditional inputs of capital and labor that formulate the textbook Solow model. Therefore, the production function, which is consistent with my analysis, is $Y = A^{\theta} K^{\beta} L$

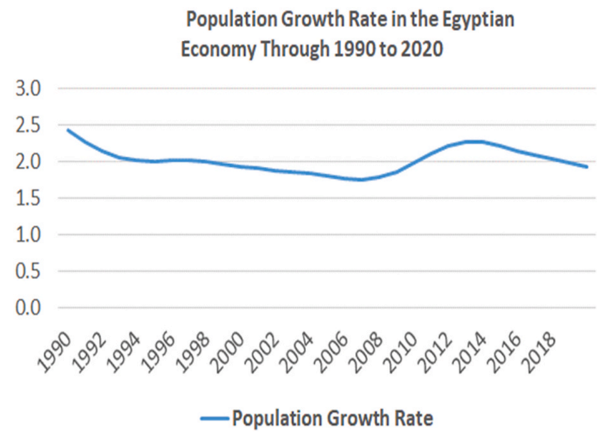

Fig. 9. Population growth rate in the egyptian economy through 1991 to 2019.

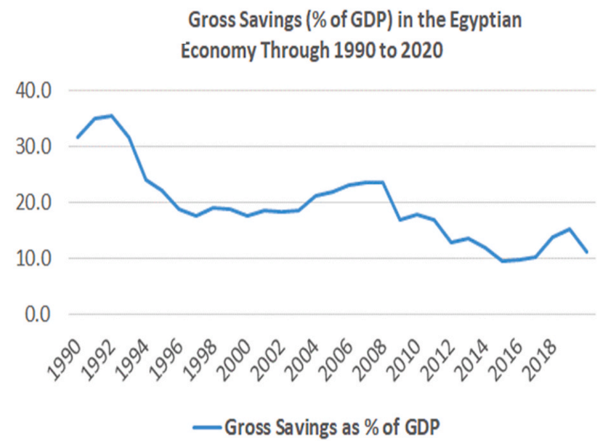

Fig. 10. Gross savings (% of GDP) in the egyptian economy through 1991 to 2019.

$^{\alpha}$ H $^{\delta}$.

In this model, output is produced by means of physical capital, HC, and labor, which is used for investing in physical capital, HC, and consumption. This paper does not assume CRS but rather lets the calculations of θ, β, α, and δ based on real data determine the econometric estimations. The period of study is classified into four generations of reform: the first generation includes 1991–2000, the second and third generations cover 2001–2010, and the fourth generation includes 2011–2019.

Using data for Egypt in (PWT) version 10.0, the production function was estimated by using the most recent constructed capital services series instead of the traditional capital stock series to avoid underestimating the weight of short-lived assets. Quantile Regression (QR) estimates for quantiles 0.1 through 0.9 that investigated the contribution of factors of economic growth showed varied results. Productivity's coefficient increased from 0.27 in Q1 to 0.60 in Q8 which means that productivity has clearly had a large impact on the higher stages of economic growth. Also, the higher income segmentations we go, the higher impact of productivity it gets. This can be attributed to technological progress and accumulation of knowledge where the high-income segmentations acquire their lion's share. On the other hand, both Capital and Human Capital are suffering from a gradual decrease in their contribution to growth. It is observed that coefficients of K decreased gradually from 0.3 in Q1 to 0.1 in Q9 and coefficients of HC declined from 0.15 for Q1 to reach 0.04 for Q9. Therefore, the main culprit behind this phenomenon is the deficiency in the savings rate and the increase in the population growth rate. With regard to labor, it is investigated that it has a negative coefficient across the four generations of economic reform. It declined from −1.03 for Q1 to become −1.46 for Q9. It can be concluded that the Egyptian economy is filled with disguised unemployment and exhausts all its potential for job creation. Consequently, investigating the evolution of the output and inputs of production along with factor inputs' contribution to economic growth, one can conclude the following findings.

First, despite economic reform over the four generations, the growth of output is continuing to erode over the period of study. The total amount of GDP growth achieved in the first generation was 49.5%, which declined to 49.4% for the second and third generations, and finally eroded to 37.9% in the fourth generation. Consequently, the average annual GDP growth rate declined from 4.95% in the first generation to 4.2% in the fourth generation, after all efforts of reform. This study determines that the main reason underlying this continuous attrition is the deterioration of capital accumulation due to a low level of investment.

Second, the contribution of capital seems to continuously decline. The main culprit behind this phenomenon is the deficiency in the savings rate and increase in the population growth rate. According to the augmented Solow model, weak capital accumulation erodes economic growth. This process of continuous corrosion happens due to the lower saving rate, which leads to lower income in the steady state, which has a crucial role in decreasing the level of HC, especially when the rate of HC accumulation is declining. Therefore, a lower savings rate becomes the main culprit behind the attrition of TFP and the lower contribution of capital. In addition, a higher population growth rate impedes economic growth since the available capital must be distributed more meagerly across a greater population and labor force. HC must also be distributed more meagerly, which in turn leads to a lower level of TFP and more abrasion to capital's contribution.

Third, capital was the highest contributor and most important factor in economic growth through the first three generations (i.e., 1991–2000 and 2001–2010). However, HC surpassed capital during the last period (i.e., 2011–2019) to become the main engine for economic growth in the Egyptian economy. Fig. 2 shows that the trend of economic growth is neatly related to the trends of HC, TFP, and capital, which in turn are heavily affected by volatility in the savings and population growth rates. As a result, the economic growth cycle in the Egyptian economy is determined by the savings and population growth rates. When these two rates enable HC, TFP, and capital to boom, strong capital accumulation appears and boosts economic growth and vice versa.

Fourth, labor's contribution is negative over the four generations, which means that an increase in labor input causes output to fall. This indicates that the Egyptian economy is filled with disguised unemployment. Also, it reflects that the economy exhausts all its potential in job generation, up to the current levels, accumulation, and contributions of HC, TFP, and capital. In addition, enhancement of labor's contribution is closely related to the advancement of the contribution of TFP and HC. Moreover, the retreat of the importance of both labor and capital in Egypt's economic growth has occurred because of the tangible progress in the shares of TFP and HC, respectively.

Of course, the increasing trend of contributions and shares of TFP and HC to Egypt's economic growth is a bright spot. However, this promising spot is raising a crucial and urgent question regarding whether the economy can stay on this path, which leads to economic growth, especially while the traditional factor inputs, labor and physical capital, are in retreat.

Fifth, the findings indicate that it is important and significant to acknowledge the role of HC as well as physical capital in both economic and income growth in Egypt. The use of QR and the augmented Solow model have proven that changes in saving, HC, TFP, and population growth explain the boom–bust cycle of economic growth and differences in income per capita across income segments in Egyptian society and their tendency toward convergence.

Lastly, it is better for the Egyptian government to implement policies that increase the savings rate to revive investment not only in physical capital but also in HC. Otherwise, economic growth and income convergence in Egypt will have little chance of achieving any tangible improvement. It is clear that the present paper has limitations where it is considered as an investigation and modeling factors of production that contributes to economic growth. Therefore, future research must explain the reasons underlying the volatility in the savings rate in Egypt's economy and the optimal policies to promote savings, potentially to double it from its current level. I expect political stability, education policies, research and development policies, tax policies, and financial policies to raise the savings rate should be included as determinants of fluctuations in economic growth. It is also predicted that the augmented Solow model will be considered the most accurate framework for fully investigating the impact of these newly proposed determinants on the level of economic well-being in Egypt.

Author contribution statement

Abdelmonem Lotfy Mohamed Kamal: Conceived and designed the analysis; Contributed to analysis; Analyzed and interpreted the data; Wrote the paper. Mostafa E. AboElsoud: Contributed to analysis; Analyzed and interpreted the data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no competing interests.

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