



Income inequality, economic growth, and structural changes in Egypt: new insights from quantile cointegration approach

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Abstract

Income inequality is an important issue in achieving sustainable growth in developing economies. However, there is a dearth of studies that examine the distributional effects of structural changes accompanying economic development policies in developing economies, especially Egypt. This study examines how income inequality has been affected by economic growth and the structural changes that have occurred in Egypt during the previous four decades. Unlike many empirical studies, the study applies an asymmetric methodology to capture the potential nonlinear effects of growth and structural changes on different locations of income inequality using the Quantile Autoregressive Distributed Lags model (QARDL). Results confirm an asymmetric cointegration relationship among variables and the speed of adjustment to catch up with the long-run equilibrium path differs significantly across different quantiles which confirms the asymmetric behavior. While the disequilibrium is corrected in the short run at a speed of 65 to 64% for the lower quantiles, the speed slows down to reach 55 to 58% at the upper locations of the Gini coefficient. Economic growth has a heterogeneous effect across different quantiles of inequality; moreover, the inverted U-shaped relationship is confirmed only across the lower half of quantiles. This implies that the Kuznets hypothesis is valid only when inequality becomes lower than its current levels in Egypt. Results also confirm the high improving distributional effect of urbanization in Egypt across all quantiles. Thus, it is useful for economic policymakers to implement policies that accelerate the urbanization process to reduce income inequality in Egypt.

Keywords Asymmetric cointegration · Economic growth · Income inequality · Quantile autoregressive distributed lags · Structural change

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1 Introduction

Debates on income inequality and its effects have become a common issue in the recent theoretical and empirical literature. After many years of ignoring issues of income distribution and equity, targeting poverty, and reducing inequality have now occupied an important part of the main mission objectives for many international financial and development agencies. The World Bank announced in April 2013 its interest in ending extreme poverty and reducing inequality via sharing prosperity in every country by 2030 (World Bank 2016). The World Bank has re-evaluated the relevance of eradicating poverty and lowering income inequality by adopting economic policies that accelerate growth in income of the bottom 40% of the population (Basu and Stiglitz 2016).

For many years, reducing income inequality has not been a priority for the World Bank or the International Monetary Fund, and has not occupied the interests of the mainstream macroeconomists who believed that reducing inequality was a matter of time and would happen automatically after the economy had achieved a certain level of economic development. This hypothesis, known as the inverted U-curve, presented by Simon Kuznets in the mid-1950s (Kuznets 1955), was supported by the decline in income inequality in many economies especially in the USA after World War II until the late 1970s (Atkinson 2016). However, the golden age of capitalism did not last long as income inequality began to rise significantly in the USA and many Western economies since the late 1970s (Lee 2021). These new trends in inequality led to the emergence of some new facts about the pattern of economic growth and income distribution that are fundamentally different from Kuznets' inverted U-curve hypothesis. One of the new stylized facts that contradict the mainstream views and observed by Joseph Stiglitz is that inequality in both wages and non-wages besides overall income inequality has increased in many countries since the 1980s, and that, unlike the historical constancy of capital/output ratio confirmed by Nicholas Kaldor, more than half a century ago, as a central stereotyped fact of modern economic growth characteristics (Kaldor 1955, 1961), there is a marked increase in this ratio in many countries at least during the past three decades (Stiglitz 2016). Increasing the capital/output ratio means a further deterioration in the structure of income distribution at the expense of wage incomes, thus exacerbating income inequality. These new facts are driven and supported by new data about inequality and economic growth in many countries and directed researchers to reconsider the inequality–growth relationship. In this context, the availability of data on the evolution of income distribution for most countries of the world has helped scholars to study income inequality from a global rather than a national perspective (Lakner and Milanovic 2016; Milanovic 2016). The new perspective revealed new features of the effect of growth on inequality that differ greatly from the Kuznets theory of inverted U-curve to describe the evolution of global inequality. Using data from the World and Wealth Income Database over the period 1980–2016, Alvaredo et al. (2018) found an elephant shape of the global income inequality which is reflected in the high growth rate in income of the median affected by progress in both India and

China and sharpening growth rates at the top, while the performance of income growth above the median was modest.

Increasing global interest in reconsidering the importance of reducing income inequality was not a coincidence. Rather, many writings that analyzed the drivers of the 2007–2008 global recession shed light on the importance of increasing income inequality to be one of the main causes that strongly led to this sharp recession (Irvin 2011; Stefani 2020). Some works support the role of increasing inequality in explaining the recession via its role in boosting loans to finance consumption. In light of low incomes and high inequality, increasing borrowing from banks to finance consumption resulted in the inability of the majority of borrowers to repay, a dangerous situation resulting in weakening consumer debt sustainability (McCombie and Spreafico 2017). Then, the banking crisis was exploited in the USA and transmitted to the world.

Global interest in reconsidering income inequality did not find an equivalent interest in Egypt. Egypt is still a developing country and classified as a low-middle-income country according to the World Bank classification. As Egypt is still struggling to achieve economic development, notable structural changes have occurred during the last four decades. Industry's contribution in the total value added has increased from 25.4 to 33.65% while agriculture share has significantly shrunk from 27.6 to 11.4%. On the other hand, the rate of urbanization in Egypt has decreased from 43.3% in 1975 to 42.7% in 2017. The same decreasing trend has occurred in the percentage of foreign trade in GDP from 53.7 to 45.12% during the period 1975–2017 (World Bank 2021). Despite these structural changes, Egypt achieved a relatively low average growth rate in real GDP per capita that did not exceed 3.14% during the period 1975–2017. This growth performance is relatively low compared to the growth rates achieved by many other countries such as Malaysia, Singapore, and South Korea, during the same period.

It is worth noting that the previous developments in economic growth and the structural changes that occurred in Egypt during the past four decades were accompanied by the exacerbation of income inequality. According to the Standardized World Income Inequality Database (SWIID), the Gini coefficient, which measures the degree of income inequality, has increased in Egypt from 0.36 in 1975 to 0.41 in 2017 (Solt 2020). Moreover, the income share of the richest 10% of the population increased from 26.7% in 1990 to 27.9% in 2015, whereas the income share of the richest 20% increased from 39.9% in 1995 to 41.5% in 2015 (World Bank 2021). These developments in economic growth and structural changes, as well as the increasing trend in income inequality during this relatively long period, require more analysis to capture the potential long-run relationships among these variables to amend any shortcomings in economic policies and support the development path in Egypt. Figure 1 supports a positive relationship between GDP per capita and income inequality measured by the Gini coefficient in Egypt over the period 1975–2017.

The worsening trend in income distribution pattern over the last four decades raises several questions about its causes besides its effects on achieving sustainable economic growth in Egypt, as a developing country seeks to get out of the middle-income countries' trap to catch up with advanced economies. Rising inequality may

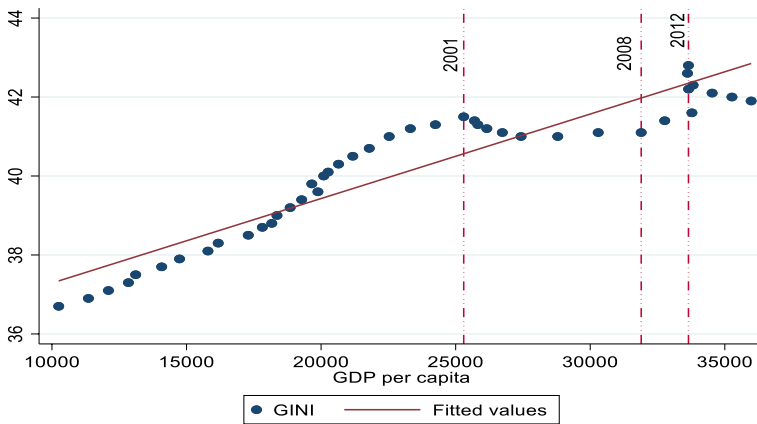


Fig. 1 Gini coefficient at different levels of GDP per capita in Egypt over the period 1975–2017. Data on GDP per capita are extracted from the World Bank (2021) and fixed at 2010 prices in local currency. The Gini coefficient data are extracted from versions 8–9 of the Standardized World Income Inequality Database (SWIID) based on Solt (2020)

hurt economic growth (Adams and Page 2003; Qin et al. 2009) as growth loses the sustainability that may not be achieved considering increasing inequality in favor of the rich. Income concentration in the hands of a small percent of the population reduces the aggregate demand by most of the society (Auclert and Rognlie 2017), and with the inability of the Egyptian economy, in its current state, to compete in global markets of goods and services, it has become difficult to compensate the decline in domestic demand relying on external demand for Egyptian exports. This critical situation confirms the need to reconsider income inequality because of its potential effects on the sustainability of economic growth in Egypt.

Despite the overlapping relationship of inequality with growth, the main task of this study is to determine the impact of both economic growth and structural changes accompanying the liberal-oriented economic development policies on income inequality in Egypt during the period 1975–2017. Several reasons call for further analysis concerning the causes of income inequality in Egypt. First, there is a dearth of published empirical studies on the determinants of income inequality in Egypt. Moreover, much of the published work is only concerned with monitoring the evolution of income distribution structure without exploring the reasons that produced this structure (Krafft and Davis 2021; Majbouri 2017). Second, as explained above, income inequality is an important factor affecting the sustainability of economic growth. Empirical works that investigated the drivers of economic growth concluded that many developing and emerging economies that achieved continuous and high economic growth rates during the previous four or five decades were characterized by a low level of income inequality (Forbes 2000). For example, the average real GDP per capita in South Korea grew by 5.8% annually, while the average Gini index of income inequality did not exceed 0.31 during the period 1975–2017 based on Solt (2020) compared to the average growth of 3.14% and high average Gini coefficient of 0.41 in Egypt during the same period. In the opposite case, studies also

indicated that countries with high levels of inequality, such as Latin American countries, failed in achieving high and sustained growth rates (Amarante 2014; Williamson 2015). This uneven performance in growth rates at different levels of inequality means that inequality and equity may make a fundamental difference in economic performance (Stiglitz and Yusuf 2001), and then, inequality does matter for Egypt.

Third, the study argues that augmenting the effects of structural changes on income distribution is necessary to understand the drivers of inequality in a developing country like Egypt. The advanced stages of economic development that Simon Kuznets talked about, in which economic growth reduces inequality, are resulted from deep structural changes within the economy. Despite this, many recent studies have overlooked the impact of structural changes when examining the distributional effects of growth in different developing economies (e.g., Nandan and Mallick 2021; Shahbaz et al. 2014; Suárez Álvarez and López Menéndez 2020). This shortcoming makes the analysis incomplete, especially when it concerns developing economies. Therefore, when investigating the determinants of income inequality in Egypt, it is important to include structural changes in the estimable model. To do this, the study uses both the share of industry in the total value added and the evolution of the urbanization rate to express the structural changes in Egypt. Also, the study adds the contribution of agriculture and the percentage of foreign trade in GDP to capture their effects on income distribution over the past four decades.

Finally, despite the valuable findings of recent empirical studies in understanding the inequality–growth relationship, most of these studies have been generated under a linear hypothesis between these two variables (e.g., Bartak and Jabłoński 2020; Caraballo et al. 2017; El-Shagi and Shao 2019; Qin et al. 2009). However, the current study adopts a different methodology benefiting from recent advanced developments in econometric techniques introduced by Cho et al. (2015). These developments enable us to explore the drivers of income inequality under an asymmetric or nonlinear framework based on the quantile autoregressive distributed lags approach QARDL developed by Cho et al. (2015). Studying the distributional effects of economic growth and structural changes within an error correction model (ECM) helps to capture the different potential distributional effects in both the short and long runs. This is of importance to the policy implications for monitoring the behavior of these variables in the short and long periods through the economic development path in Egypt over the previous four decades. Many empirical studies employed the ECM and confirmed a long-run equilibrium relationship between growth and income inequality. Risso et al. (2013) studied the long-run equilibrium relationship between economic growth and income inequality in Mexico over the period 1968–2010. They concluded that there is a cointegration relationship between these two variables. Hoover et al. (2009) studied the effect of the business cycles on income inequality using both linear ARDL of and nonlinear asymmetric cointegration tests in Italy during the period 1967–2012. Shahbaz (2010) applied an ECM to investigate the cointegration relationship between income inequality and economic growth in Pakistan over the period 1971–2005. The results of the ARDL supported the validity of the Kuznets inverted U-curve relationship hypothesis in explaining the effect of economic growth on income inequality. On the other hand, nonlinear cointegration was tested by Ghosh (2020) who applied the Shin et al. (2014) methodology to data for

the period 1980–2015 to explore the asymmetric cointegration between economic growth and income inequality in ASEAN countries. It is noted that studying cointegration according to previous studies assumes that the speed of error correction process is symmetric according to the ARDL model, but this speed may differ across different levels of income inequality and then the distributional effects of economic growth and structural change may be asymmetric across different locations or quantiles of the conditional distribution of income inequality. In this regard, the study aims at exploring the potential asymmetric cointegration among income inequality, economic growth, and structural changes in Egypt over the period 1975–2017. To our knowledge, this is the first study that employs the QARDL model to capture the income inequality drivers in Egypt.

The study is organized as follows, the second section briefly surveys the relevant literature, while the third section runs a preliminary analysis of the data used and illustrates the QARDL methodology. The fourth section presents results and discussions. Finally, the fifth section concludes.

2 Relevant literature

Despite the large number of studies that attempted to understand the relationship between growth, structural changes, and income distribution, the results are still not conclusive, and no consensus is settled on the interrelationships among these variables. As argued by Caraballo et al. (2017), there are two main approaches in the theoretical works describing the inequality–growth relationship, the classic and the political economy. The classic or standard approach advocates a positive relationship between inequality and growth described in many works (Bénabou 1996; Forbes 2000; Galor and Tsiddon 1997; Kaldor 1955; Saint-Paul and Verdier 1993; Stiglitz 1969). These studies attribute the positive effect of inequality on growth to its positive impact on some factors necessary to stimulate economic growth, such as the saving rate, technological change, and capital accumulation. Poor classes have a lower marginal propensity to save, so increasing their incomes via redistribution policies results in rising consumption not saving (Brida et al. 2020). Therefore, the rate of capital accumulation that supports economic growth will be negatively affected if income inequality decreases. As the rich have a greater marginal propensity to save compared to the poor, more unequal income will be reflected in high saving rates (Stiglitz 1969).

Several recent empirical studies supported the classic view of the positive effect of inequality on the saving rate and economic growth. Using the panel GMM methodology, Koo and Song (2016) introduce empirical evidence that supported the positive effect of inequality on saving rates. They argue that this positive effect is stronger in countries with an advanced system of financial development. Moreover, the effect of inequality becomes more powerful the greater the difference between the marginal propensity to save between rich and poor. Chen et al. (2017) find evidence that supports the positive impact of income inequality on the saving rate in China; they argue that aggregate saving is not only affected by income level but also increased in cases of high levels of income inequality. Other scholars (e.g., Chu and

Wen 2017; Gu et al. 2020) attributed the significant increase in saving rates that occurred in China to the remarkable increase in income inequality since the beginning of the 2000s. On the other hand, Smith (2001) finds that credit market imperfections that do not provide financing to the poor are one of the most important channels in explaining the positive effect of inequality on private saving rates.

Contrary to the classic views, the political economy approach holds that income inequality negatively affects growth (Alesina and Perotti 1996; Alesina and Rodrik 1994; Persson and Tabellini 1991, 2002). A high level of income inequality leads to social and political instability, and then the investment rate decreases, and economic growth stagnates. In highly unequal economies, applying income redistribution policies to reduce inequality may harm investment if income redistribution depends on increasing tax rates (Brida et al. 2020). Thus, low levels of income inequality will not require applying redistribution policies that harm investment and, consequently, durable economic growth (Berg et al. 2018). There are a few recent studies that came out of these two approaches. These studies affirm a non-monotonic relationship between inequality to growth. For example, Balcilar et al. (2021) indicated that the effect of inequality on economic growth is shaped by an inverted U-curve relationship, where economic growth is positively affected when inequality is relatively low and after a certain threshold of the Gini coefficient (0.359), the effect of inequality on growth becomes negative.

Just as the effect of inequality on economic growth has been debated, there is also much debate about the effect of growth and structural changes on income inequality. There was a lack of interest in the determinants of inequality until the late 1970s influenced by the dominance of Friedman's consumption theory and Kuznets's inverted U-curve hypothesis. Experience of the post-World War II in the USA and other Western countries proved that rising economic growth did not result in decreasing average propensity to consume as predicted by Keynesian proponents. Rather, the APC remained stable (Drennan 2017). Thus, there is no need to reduce inequality to prevent lower consumption and effective demand. Moreover, as predicted by Simon Kuznets, income inequality began to decrease in many Western economies, influenced by the high growth achieved until the late 1970s. These developments were enough to ignore income inequality because it will be improved automatically, and it will not harm aggregate demand and thus economic growth. The nonlinear relationship described by Kuznets to explain the behavior of inequality during different economic growth stages was also confirmed in several empirical works. However, other studies rejected this hypothesis and considered that the relationship between growth and inequality is shaped by U-curve rather than Kuznets inverted U-curve (Blanco and Ram 2019). Kim et al. (2011) employ panel mean group estimator PMG using data from the USA over the period 1945–2004 to capture the long-run relationship between income inequality and development. They find a U-curve between these two variables where inequality declines during the early phase and then increases in the later phases of development.

Few researchers were satisfied with not only monitoring the impact of growth on inequality, but their empirical research extended to find out the effect of structural changes on inequality, given that the economic growth, especially in developing economies, is a result of the structural changes that accompany the development

process (Aizenman et al. 2012; Wan et al. 2016). Structural changes include many manifestations, but changes in the relative shares of different sectors in the value added represent the most important phenomenon of structural change. In this context, the empirical literature contains mixed results about the distributional effects of structural changes. Wan et al. (2016) find an inverted U-curve between structural changes and income inequality in China. Structural changes in the early stages of development lead to an increase in income inequality and then decreases in the later stages. Structural changes, like economic growth, do not occur everywhere, and therefore not everyone benefits from them immediately, and this explains increasing inequality in the early stages of structural changes. But with more structural change that requires workers to acquire the skills needed to transfer and work in highly productive sectors such as industry, the wages of these workers begin to increase, and thus inequality decreases as structural changes accelerate and individuals become more skilled and adaptable. This result is compatible with Kuznets's hypothesis about the growth–inequality nexus; however, it contradicts other studies such as Aizenman et al. (2012) which emphasized U rather than inverted U-shaped relationship between inequality and structural changes. Also, some aspects of structural changes, like the evolution of industry share in output besides urbanization, affect income inequality. Using data from 27 countries over the period 1991–2014, Mehic (2018) finds a negative distributional effect of industrial employment in high and middle-income economies. Wan et al. (2022) find that well-managed urbanization reduces income inequality in developing countries. Given that most of these economies suffering from structural fiscal deficits, relying on fiscal policies to reduce inequality is infeasible considering the limited impact of fiscal policy on redistributing income to reduce inequality. Thus, increasing urbanization rates will play an important role in reducing the income gap between rural and urban areas, in addition to its positive impact on economic growth rates.

3 Methodology and data

3.1 Data and preliminary analysis

The study uses data covering the period 1975–2017. Table 1 describes variables and data sources. Table 2 and Fig. 2 show some statistical characteristics and evolution of time series paths over the period 1975–2017. This period, which extends for more than four decades, enables us to monitor the structural developments that took place in the production structure of the Egyptian economy through accounting for the changes in relative shares of industry and agriculture in total value added, as well as urbanization and foreign trade. Moreover, it allows us to study the behavior of economic growth in the long run and its relationship to the pattern of income distribution to capture any asymmetric behavior. Statistical characteristics indicate that the average Gini coefficient during the period reached 0.401 reached its lowest level at 0.367 and peaked at 0.428. According to the standard deviation, GDP per capita represents the most volatile variable during the study period. This relatively high volatility in GDP per capita indicates that

Table 1 Variables and data sources

Variable	Symbol	Description	Source
Income inequality	gini	A measure of income inequality. It is the Gini coefficient of disposable income inequality; its value ranges from 0 to express perfect equality and 1 which means perfect inequality	Solt (2020)
Gross domestic product per capita	gdp	Gross domestic product divided by midyear population. Data are in constant 2010 local currency	World Bank (2021)
Industrialization	ind	Share of industry value added in total value added	World Bank (2021)
Urbanization	urb	Percentage of population living in urban areas in the total population	World Bank (2021)
Agriculture	agri	Share of agriculture value added in total value added	World Bank (2021)
Openness	open	Percentage of the sum of exports and imports in gross domestic product	World Bank (2021)

Table 2 Descriptive statistics

Variables	Obs.	Mean	Std. Dev.	Min	Max	Skew.	Kurt.
gini	43	0.401	0.017	0.367	0.428	-0.462	2.028
gdp	43	9.998	0.345	9.235	10.491	-0.344	2.214
gdp ²	43	19.99	0.69	18.47	20.981	-0.344	2.214
ind	43	0.315	0.041	0.238	0.399	0.2	2.331
urb	43	0.432	0.005	0.427	0.44	0.426	1.577
agri	43	0.164	0.039	0.113	0.277	0.113	0.277
open	43	0.508	0.112	0.302	0.745	0.302	0.745

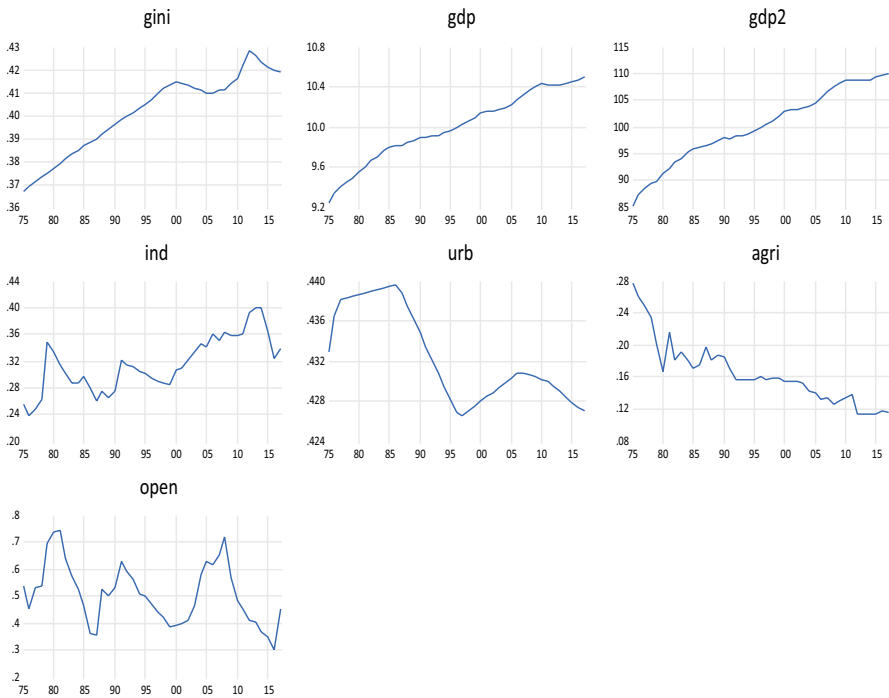


Fig. 2 Time-series evolution (1975–2017)

the economic growth in Egypt is subject to factors that are not stable such as oil prices and tourism and does not depend on more stable factors that are related to the production structure. This variability in GDP per capita supports our view to analyze the effects of economic growth on inequality in a nonlinear framework rather than the traditional linear approach that has dominated many empirical studies.

3.2 Model specification

This study seeks to estimate the distributional impacts of structural changes accompanying economic development policies implemented in Egypt during the previous four decades starting from 1975. As explained previously, the structural changes are expressed through tracking what happened in both industrialization and urbanization in Egypt during this period. So, our initial econometric specification can be expressed as follows:

$$\text{gini}_t = \beta_0 + \beta_1 \text{gdp}_t + \beta_2 \text{gdp}_t^2 + \beta_3 \text{ind}_t + \beta_4 \text{urb}_t + \beta_5 \text{agri}_t + \beta_6 \text{open}_t + \epsilon_t \quad (1)$$

where β_0 and ϵ_t refer to constant and the error term, respectively, all the variables are expressed in logarithm, the coefficients β_i where $i = 1, 2, 3, 4, 5$ and 6 , estimate the long-run elasticities of the Gini coefficient (gini) as a measure of income inequality with respect to gross domestic product per capita (gdp), gross domestic product per capita squared (gdp^2), industrialization (ind), urbanization (urb), agriculture (agri), and openness (open) in time t . Equation (1) includes several variables commonly used in empirical studies that analyze the determinants of patterns of income distribution and income inequality. The Gini coefficient data are extracted from versions 8–9 of the Standardized World Income Inequality Database (SWIID) based on Solt (2020).

The Kuznets inequality inverted U-curve hypothesis introduced by Kuznets (1955) has been considered by including both gdp and gdp^2 to capture potential nonlinear relationship between income inequality and economic growth. Kuznets's hypothesis indicates that income inequality increases in the early stages of economic growth, and then decreases gradually in the advanced stages after achieving a certain income level. Thus, Kuznets' inequality–growth hypothesis will be satisfied in Eq. (1) if $\beta_1 > 0$ and $\beta_2 < 0$. Although this hypothesis has been extensively studied in many empirical studies [see the recent survey by Mdingi and Ho (2021)], there is a dearth of studies that have tested this hypothesis in Egypt.

The study covers a period from 1975 to 2017. This period is relatively sufficient to capture the structural changes that have taken place in the Egyptian economy. Structural change is a multidimensional issue. According to Syrquin and Chenery (1989) structural change refers to a shift in resources from traditional sectors (agriculture) to advanced sectors (manufacturing and services). Thus, the contributions of economic sectors to value added will change reflecting the structural changes accompanying economic development process. Moreover, the transfer of production factors, especially labor, from the traditional sectors to the industrial areas leads to the growth of cities and expands the urban areas within the economy (McGowan and Vasilakis 2019). Accordingly, to express the structural change in the model, the study uses both the ratio of value added of the industrial sector to GDP and the evolution of population proportion living in urban areas. We believe that including both industrialization and urbanization in the estimable model contributes to understanding the distributional impacts of structural change that occurred in Egypt during the last four decades. Many empirical and theoretical studies analyzed the distributional effect of industrialization (e.g., Dumke 1991; Foster and Rosenzweig 2003;

Koo 1984; Rozelle 1994; Wang 2019; Yao 1997), and recently, the impact of both industrialization and urbanization on income inequality has been reviewed in many countries that differ in their income levels. It is noted that different levels of income lead to different impacts on income inequality (Ali et al. 2022). Recently, some studies have shown that the change in the relative weight of agriculture in GDP and trade openness can contribute to explaining the changes that have occurred in income inequality in many economies (Cheng and Wu 2017; İşcan and Lim 2022). So, the study also adds both the evolution of the agriculture added value (agri) as well as trade openness (open) proxied by the percentage of foreign trade to GDP to monitor the impact of other structural changes that may affect income distribution pattern in Egypt during the study period.

3.3 Quantile autoregressive distributed lags model

The study applies the QARDL methodology developed by Cho et al. (2015) to explore the potential cointegration and asymmetric effects of economic growth and structural changes variables on income inequality in Egypt. To understand the QARDL model, we follow (Aziz et al. 2020; Baek 2020; Lahiani et al. 2019) by presenting first the basic ARDL model as follows:

$$\begin{aligned} \Delta \text{gini}_t = & a_0 + \sum_{i=1}^p a_{1i} \Delta \text{gini}_{t-i} + \sum_{i=0}^{q1} a_{2i} \Delta \text{gdp}_{t-i} + \sum_{i=0}^{q2} a_{3i} \text{gdp}_{t-i}^2 + \sum_{i=0}^{q3} a_{4i} \Delta \text{ind}_{t-i} \\ & + \sum_{i=0}^{q4} a_{5i} \Delta \text{urb}_{t-i} + \sum_{i=0}^{q5} a_{6i} \Delta \text{agri}_{t-i} + \sum_{i=0}^{q6} a_{7i} \Delta \text{open}_{t-i} + b_1 \text{gini}_{t-1} + b_2 \text{gdp}_{t-1} \\ & + b_3 \text{gdp}_{t-1}^2 + b_4 \text{ind}_{t-1} + b_5 \text{urb}_{t-1} + b_6 \text{agri}_{t-1} + b_7 \text{open}_{t-1} + e_t \end{aligned} \quad (2)$$

where Δ represents difference operator, a_0 is the constant and the error term is represented by e_t . All the variables are defined above. The short-run behavior of the Gini coefficient of income inequality, GDP per capita, GDP per capita squared, industrialization, urbanization, agriculture, and openness can be captured by the coefficients $a_1, a_2, a_3, a_4, a_5, a_6$, and a_7 , respectively, depending on the Akaike Information Criterion (AIC) in determining the lag lengths $p, q_1, q_2, q_3, q_4, q_5, q_6$, while the long-run behavior of these variables can be estimated by the coefficients $b_1, b_2, b_3, b_4, b_5, b_6$, and b_7 , respectively.

The problem with the ARDL model is its inability in detecting nonlinear relationships that may exist among variables. This defect may result in losing important information about the nature of the relationships between variables in both the short and long runs. Although this problem has been considered in the nonlinear autoregressive distributed lags model (NARDL) developed by Shin et al. (2014), which has been used in many recent studies (e.g., Ali 2021; Zribi and Boufateh 2020); however, the nonlinearity in NARDL model does not determine by data-proceeding (Razzaq et al. 2021). The nonlinearity in NARDL is exogenously determined by taking a value of zero to the threshold not via data processing (Baek 2020, 2021). Despite the advantages of NARDL, compared to the traditional linear ARDL, in monitoring asymmetric

relationships between variables in both short and long runs, it is still providing a partial picture of the effect of the independent variables across different locations or quantiles in the response variable (Guo et al. 2021; Zaighum et al. 2021).

To overcome the shortcomings of both ARDL and NARDL models, Cho et al. (2015) modified the basic ARDL model of Pesaran et al. (2001) and proposed the QARDL model to study the behavior of variables in the short and long terms across different quantiles. According to Guo et al. (2021), the QARDL has the advantages of both the ARDL model introduced by Pesaran et al. (2001) and the quantile regression technique proposed by Koenker and Bassett (1978). Using QARDL gives us the ability to understand the relationships between variables in the short and long terms, and then, we can discover the extent of the long-run equilibrium relationship between variables, as well as monitor the error correction coefficient in the short run. QARDL also provides the possibility to explore the nonlinearity relationship (Shafiqullah et al. 2020) and potential cointegration among variables at different locations or quantiles of the response variable. Thus, the long-term equilibrium relationship between the Gini coefficient and the independent variables can be monitored across different quantiles through the QARDL model as follows:

$$\begin{aligned}
 Q\Delta gini_t = & a_0(\tau) + \sum_{i=1}^{p-1} \varphi_i^{gini}(\tau)\Delta gini_{t-i} + \sum_{i=0}^{q_1-1} \gamma_i^{gdp}(\tau)\Delta gdp_{t-i} + \sum_{i=0}^{q_2-1} \omega_i^{gdp^2}(\tau)\Delta gdp_{t-i}^2 \\
 & + \sum_{i=0}^{q_3-1} \theta_i^{ind}(\tau)\Delta ind_{t-i} + \sum_{i=0}^{q_4-1} \delta_i^{urb}(\tau)\Delta urb_{t-i} \\
 & + \sum_{i=0}^{q_5-1} \vartheta_i^{agri}(\tau)\Delta agri_{t-i} + \sum_{i=0}^{q_6-1} \gamma_i^{open}(\tau)\Delta open_{t-i} + \xi(\tau)gini_{t-1} + \beta_{gdp}(\tau)gdp_{t-1} \\
 & + \beta_{gdp^2}(\tau)gdp_{t-1}^2 + \beta_{ind}(\tau)ind_{t-1} + \beta_{urb}(\tau)urb_{t-1} + \beta_{agri}(\tau)agri_{t-1} \\
 & + \beta_{open}(\tau)open_{t-1} + \varepsilon_t(\tau)
 \end{aligned} \tag{3}$$

To avoid the potential contemporaneous correlation between the error term ε_t with $\Delta gdp, \Delta gdp^2, \Delta ind, \Delta urb, \Delta agri,$ and $\Delta open$, Eq. (3) can be represented as an error correction quantile autoregressive distributed lag model ECM-QARDL:

$$\begin{aligned}
 Q\Delta gini_t = & a_0(\tau) + \sum_{i=1}^{p-1} \varphi_i^{gini}(\tau)\Delta gini_{t-i} + \sum_{i=0}^{q_1-1} \gamma_i^{gdp}(\tau)\Delta gdp_{t-i} + \sum_{i=0}^{q_2-1} \omega_i^{gdp^2}(\tau)\Delta gdp_{t-i}^2 \\
 & + \sum_{i=0}^{q_3-1} \theta_i^{ind}(\tau)\Delta ind_{t-i} + \sum_{i=0}^{q_4-1} \delta_i^{urb}(\tau)\Delta urb_{t-i} \\
 & + \sum_{i=0}^{q_5-1} \vartheta_i^{agri}(\tau)\Delta agri_{t-i} + \sum_{i=0}^{q_6-1} \pi_i^{open}(\tau)\Delta open_{t-i} \\
 & + \xi(\tau)\left(gini_{t-1} - \beta_{gdp}(\tau)gdp_{t-1} - \beta_{gdp^2}(\tau)gdp_{t-1}^2 - \beta_{ind}(\tau)ind_{t-1} \right. \\
 & \left. - \beta_{urb}(\tau)urb_{t-1} - \beta_{agri}(\tau)agri_{t-1} - \beta_{open}(\tau)open_{t-1} \right) + \varepsilon_t(\tau)
 \end{aligned} \tag{4}$$

where $\tau \in \{0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 0.95\}$ represents the quantiles. The cumulative short-run effect of the previous income inequality can be captured by $\varphi_*^{\text{gini}} = \sum_{i=1}^{p-1} \varphi_i^{\text{gini}}$, while the overall short-run effects of current and previous levels of gross domestic product, squared of gross domestic product, industrialization, urbanization, agriculture, and openness are obtained by $\gamma_*^{\text{gdp}} = \sum_{i=0}^{p-1} \gamma_i^{\text{gdp}}$, $\omega_*^{\text{gdp}^2} = \sum_{i=0}^{p-1} \omega_i^{\text{gdp}^2}$, $\theta_*^{\text{ind}} = \sum_{i=0}^{p-1} \theta_i^{\text{ind}}$, $\delta_*^{\text{urb}} = \sum_{i=0}^{p-1} \delta_i^{\text{urb}}$, $\vartheta_*^{\text{agri}} = \sum_{i=0}^{p-1} \vartheta_i^{\text{agri}}$, and $\pi_*^{\text{open}} = \sum_{i=0}^{p-1} \pi_i^{\text{open}}$, respectively. However, the long-run coefficients of gross domestic product, squared of gross domestic product, industrialization, agriculture, and openness can be obtained by $\beta_{\text{gdp}^*} = -\frac{\beta_{\text{gdp}}}{\xi}$, $\beta_{\text{gdp}^{2*}} = -\frac{\beta_{\text{gdp}^2}}{\xi}$, $\beta_{\text{ind}^*} = -\frac{\beta_{\text{ind}}}{\xi}$, $\beta_{\text{urb}^*} = -\frac{\beta_{\text{urb}}}{\xi}$, $\beta_{\text{agri}^*} = -\frac{\beta_{\text{agri}}}{\xi}$ and $\beta_{\text{open}^*} = -\frac{\beta_{\text{open}}}{\xi}$, respectively.

In Eq. (4), $\xi(\tau)$ represents the error correction term in different locations or quantiles τ of the response variable, the Gini coefficient. It must be negative and significant to capture the speed of adjustment of the model in correcting the disequilibrium that occurs in the short run to move the model toward the long-run equilibrium path. Wald test is running to examine the null hypothesis of constancy of the speed of adjustment coefficient $H_0 : \xi(0.05) = \xi(0.10) = \xi(0.20) = \xi(0.30) = \dots = \xi(0.95)$. Rejecting the null hypothesis H_0 implies that the error correction term has different values deepening on different locations of the Gini coefficient and supports an asymmetric long-run relationship between considered variables. Equation (4) also requires testing for location nonlinearity or asymmetry among the estimated coefficients across different quantiles in the short and long terms. The null hypotheses of parameter constancy in the short run can be represented as follows:

$$\begin{aligned}
 H_0^{\text{short run}} &: \varphi_i^{\text{gini}}(0.05) = \varphi_i^{\text{gini}}(0.10) = \varphi_i^{\text{gini}}(0.20) = \varphi_i^{\text{gini}}(0.30) = \dots = \varphi_i^{\text{gini}}(0.95) \\
 H_0^{\text{short run}} &: \gamma_i^{\text{gdp}}(0.05) = \gamma_i^{\text{gdp}}(0.10) = \gamma_i^{\text{gdp}}(0.20) = \gamma_i^{\text{gdp}}(0.30) = \dots = \gamma_i^{\text{gdp}}(0.95) \\
 H_0^{\text{short run}} &: \omega_i^{\text{gdp}^2}(0.05) = \omega_i^{\text{gdp}^2}(0.10) = \omega_i^{\text{gdp}^2}(0.20) = \omega_i^{\text{gdp}^2}(0.30) = \dots = \omega_i^{\text{gdp}^2}(0.95) \\
 H_0^{\text{short run}} &: \theta_i^{\text{ind}}(0.05) = \theta_i^{\text{ind}}(0.10) = \theta_i^{\text{ind}}(0.20) = \theta_i^{\text{ind}}(0.30) = \dots = \theta_i^{\text{ind}}(0.95) \\
 H_0^{\text{short run}} &: \delta_i^{\text{urb}}(0.05) = \delta_i^{\text{urb}}(0.10) = \delta_i^{\text{urb}}(0.20) = \delta_i^{\text{urb}}(0.30) = \dots = \delta_i^{\text{urb}}(0.95) \\
 H_0^{\text{short run}} &: \vartheta_i^{\text{agri}}(0.05) = \vartheta_i^{\text{agri}}(0.10) = \vartheta_i^{\text{agri}}(0.20) = \vartheta_i^{\text{agri}}(0.30) = \dots = \vartheta_i^{\text{agri}}(0.95) \\
 H_0^{\text{short run}} &: \pi_i^{\text{open}}(0.05) = \pi_i^{\text{open}}(0.10) = \pi_i^{\text{open}}(0.20) = \pi_i^{\text{open}}(0.30) = \dots = \pi_i^{\text{open}}(0.95)
 \end{aligned}$$

whereas the null hypotheses of parameter constancy in the long run:

$$\begin{aligned}
 H_0^{\text{Long run}} &: \beta_{\text{gdp}^*}(0.05) = \beta_{\text{gdp}^*}(0.10) = \beta_{\text{gdp}^*}(0.20) = \beta_{\text{gdp}^*}(0.30) = \dots = \beta_{\text{gdp}^*}(0.95). \\
 H_0^{\text{Long run}} &: \beta_{\text{gdp}^{2*}}(0.05) = \beta_{\text{gdp}^{2*}}(0.10) = \beta_{\text{gdp}^{2*}}(0.20) = \beta_{\text{gdp}^{2*}}(0.30) = \dots = \beta_{\text{gdp}^{2*}}(0.95). \\
 H_0^{\text{Long run}} &: \beta_{\text{ind}^*}(0.05) = \beta_{\text{ind}^*}(0.10) = \beta_{\text{ind}^*}(0.20) = \beta_{\text{ind}^*}(0.30) = \dots = \beta_{\text{ind}^*}(0.95). \\
 H_0^{\text{Long run}} &: \beta_{\text{urb}^*}(0.05) = \beta_{\text{urb}^*}(0.10) = \beta_{\text{urb}^*}(0.20) = \beta_{\text{urb}^*}(0.30) = \dots = \beta_{\text{urb}^*}(0.95). \\
 H_0^{\text{Long run}} &: \beta_{\text{agri}^*}(0.05) = \beta_{\text{agri}^*}(0.10) = \beta_{\text{agri}^*}(0.20) = \beta_{\text{agri}^*}(0.30) = \dots = \beta_{\text{agri}^*}(0.95). \\
 H_0^{\text{Long run}} &: \beta_{\text{open}^*}(0.05) = \beta_{\text{open}^*}(0.10) = \beta_{\text{open}^*}(0.20) = \beta_{\text{open}^*}(0.30) = \dots = \beta_{\text{open}^*}(0.95).
 \end{aligned}$$

Rejecting the null hypotheses implies that there are locational asymmetries that confirm the heterogeneous effects of GDP, the square of GDP, industrialization, urbanization, agriculture, and openness at different locations of the Gini coefficient of income inequality. These asymmetries imply that the coefficients $\varphi_i^{\text{gini}}(\tau)$, $\gamma_i^{\text{gdp}}(\tau)$, $\omega_i^{\text{gdp}^2}(\tau)$, $\theta_i^{\text{ind}}(\tau)$, $\delta_i^{\text{urb}}(\tau)$, $\vartheta_i^{\text{agri}}(\tau)$, and $\pi_i^{\text{open}}(\tau)$ are quantile dependent on the short run. The same implication can be inferred when rejecting the null hypotheses in the long run, which means that the coefficients $\beta_{\text{gdp}^*}(\tau)$, $\beta_{\text{gdp}^{2*}}(\tau)$, $\beta_{\text{ind}^*}(\tau)$, $\beta_{\text{urb}^*}(\tau)$, $\beta_{\text{agri}^*}(\tau)$, and $\beta_{\text{open}^*}(\tau)$ differ according to different quantiles of income inequality in the long run.

3.4 Unit root testing approach

Employing both ARDL and QARDL techniques requires that the integration order of all series does not exceed $I(1)$ so that the F-statistic remains valid in judging the existence of cointegration (Shahbaz et al. 2012). Both two techniques, ARDL and QARDL, are valid when all variables are integrated of order one or zero, or a mix of $I(0)$ and $I(1)$. To confirm these integration preconditions of the variables, the study applies two different approaches in testing unit roots. The first is represented by the traditional unit root tests commonly used in the empirical literature, which includes a lot of tests like the augmented ADF test (Dickey and Fuller 1979), Phillip–Perron test, Phillips and Perron (1988), and the ADF-GLS test developed by Elliott et al. (1992). These tests ignore the potential impacts of structural breaks on changing the mean or variance of series and therefore, its results may be biased (Shahbaz et al. 2012). Thus, the non-stationarity of the time series in the level may be due to the occurrence of structural breaks in the variables (Mallick et al. 2021). Neglecting this may result in misleading results about the integration order of the time series and the choice of the correct econometric method. To avoid these potential shortcomings and their consequences, the study also uses the second approach of unit root tests, which considers the effect of structural breaks on the time path of both mean and variance of the variables. There are many of these tests that have been used in the empirical literature, some of these tests like Perron (1989) assume prior knowledge of the structural break date and treat it in the model exogenously. Other tests assume that the breaks are unknown and determined endogenously (Lee and Strazicich 2003; Zivot and Andrews 2002). In this study, we follow many empirical studies (Rafindadi and Ozturk 2017; Shahbaz et al. 2012) and recently Ali (2022) in using the two endogenous structural breaks test (CMR) of Clemente et al. (1998), which tests the unit root under two endogenous breakpoints (Valera et al. 2017) and is characterized by its ability to conduct a unit root test in two different cases of structural changes in the mean of the series, the sudden structural breaks case called additive outliers (AO), as well as the gradual structural breaks case which is called innovative outliers (IO). CMR extended the unit root test developed by Perron and Vogelsang (1992) to be able to test the unit root when the series has two structural breaks in its mean.

To run the CMR unit root test with two structural breaks, we first estimate the following equation:

$$y_t = \mu + \theta_1 \text{DU}_{1t} + \theta_2 \text{DU}_{2t} + e_t \quad (5)$$

where DU_{1t} and DU_{2t} are dummy variables take 1 if $t >$ the time breaks TB_1 and TB_2 , and zero otherwise, respectively. Second, the estimated residual e_t of Eq. (5) is used to generate Eq. (6):

$$e_t = \sum_{i=0}^k \vartheta_{1t}DTB_{1t-i} + \sum_{i=0}^k \vartheta_{2t}DTB_{2t-i} + \varphi e_{t-1} + \sum_{i=0}^k c_i e_{t-i} + \varepsilon_t \tag{6}$$

both DTB_{1t} and DTB_{2t} are pulse variables equal to 1 if $t = TB_{1t} + 1, t = TB_{2t} + 1$ and equal to zero otherwise, respectively. If the autoregressive coefficient of the residual φ is significantly different from zero, we reject the null hypothesis of the existence of unit root under two structural breaks.

4 Results and discussion

4.1 Stationarity of the series

As already mentioned, it is necessary to confirm that the conditions for applying the QARDL model are met. Looking at the results reported in Table 3, we find that there is no variable is I(2). It is clear from the results of both the ADF, PP, and ADF-GLS tests that all time series are stationary at the first difference and become integrated with the first difference, except for the ind variable, which showed stationary at the level according to the ADF and PP tests. As shown in Table 4, the breaking points in the various variables, whether under the application of the AO or IO models, reflect the nature of the structural changes that occurred in the Egyptian economy during the study period that extends to more than four decades. For example, according to the sudden change model, the year 1991 marks the beginning of Egypt’s implementation of economic reform and structural adjustment program (ERSAP) supported by the International Monetary Fund. The ERSAP represented a structural shift in

Table 3 Unit root tests without structural breaks

Variables	Augmented Dickey–Fuller test (ADF)		Phillips–Perron test (PP)		Elliott, Rothenberg & Stock test (ADF-GLS)	
	Level	First diff.	Level	First diff.	Level	First diff.
gini	−2.052	−2.955*	−2.373	−3.023**	−0.311	−2.843**
gdp	−1.108	−3.069***	−3.530**	−4.699***	0.608	−2.096*
gdp ²	−1.008	−3.169***	−3.076**	−4.636***	0.614	−2.212*
ind	−3.158 ***	−3.446***	−6.198***	−3.446**	0.205	−2.103*
urb	−1.794	−3.072***	−2.014	−3.072**	0.408	−2.036*
agri	−2.066	−3.944***	−2.053	−8.821***	−0.567	−9.107***
open	−3.579**	−4.909***	−2.402	−4.960***	−3.631***	−4.432***

*, **, and*** refer to rejection of null hypothesis of unit root existence at 10%, 5%, and 1% significance levels, respectively. The critical values of ADF test are (−3.634, −2.952, −2.610), for PP are (−3.641, −2.955, −2.611) and for ADF-GLS are (−2.606, −2.011, −1.727) at 1%, 5%, and 10%, respectively

Table 4 Unit root test with two endogenous breakpoints (Clemente et al. 1998)

Variables	Additive outlier model (AO)			Innovative outlier model (IO)			Integration degree
	<i>t</i> -statistic	Break year (1)	Break year (2)	<i>t</i> -statistic	Break year (1)	Break year (2)	
<i>Level</i>							
<i>gini</i>	−2.656	1993	2012	−4.160	1993	2012	I(0)
<i>gdp</i>	−3.225	1995	2006	−3.147	1994	2004	I(0)
<i>gdp</i> ²	−3.155	1995	2006	−3.179	1994	2004	I(0)
<i>ind</i>	−0.828	1987	2002	−2.501	2004	2009	I(0)
<i>urb</i>	−2.690	1990	2003	1.290	1977	1995	I(0)
<i>agri</i>	−0.339	1991	2005	−3.987	1989	2002	I(0)
<i>open</i>	−3.277	1984	2006	−5.300	1980	2007	I(0)
<i>First difference</i>							
Δ <i>gini</i>	−5.745**	1998	2009	−5.634**	1999	2010	I(1)
Δ <i>gdp</i>	−6.021**	1982	2006	−5.825**	1984	2009	I(1)
Δ <i>gdp</i> ²	−5.951**	1982	2006	−6.012**	1984	2009	I(1)
Δ <i>ind</i>	−6.573**	1984	2010	−6.471**	1985	2009	I(1)
Δ <i>urb</i>	−5.751**	1990	2012	−5.856**	1985	2006	I(1)
Δ <i>agri</i>	−9.305**	1978	2002	−5.574**	1979	1991	I(1)
Δ <i>open</i>	−5.563**	2002	2006	−6.321**	1978	2007	I(1)

The critical value at 5% significance level is −5.490

** indicates significance at 5%

macroeconomic policy orientations which directed economic policies toward liberalizing many prices, unifying the exchange rates of the Egyptian pound, and implementing a wide program of privatization. The same is true for 2013, when major political regime shifts occurred in that year, representing a sudden turning point.

4.2 Linear cointegration results

To estimate Eq. (4), we first run the OLS regression to capture the results of the traditional ARDL model as shown in Table 5. According to the Akaike Information Criterion (AIC), the optimal lag lengths chose ARDL (2, 1, 1, 0, 0, 1, 0) model. Results of the ARDL model set a highly significant and negative error correction speed to reach 72.9% yearly. It is a good adjustment speed that enables the model to correct the short-run disequilibrium and catch up with the equilibrium path in the long run. All the long-run coefficients of the model are significant. It is noticed that the Kuznets hypothesis is fulfilled, as the sign of the *gdp* coefficient is positive and significant, which turned to be significantly negative for *gdp*² coefficient. The Kuznets inverted U-curve hypothesis has also been confirmed with more distributional effects of both *gdp* and *gdp*² in the short run. This result means that the deterioration that occurs in income inequality during the early stages of economic growth

Table 5 Ordinary least squares and QARDL results

Parameters	Quantile ARDL										
	$\tau = 0.05$	$\tau = 0.10$	$\tau = 0.20$	$\tau = 0.30$	$\tau = 0.40$	$\tau = 0.50$	$\tau = 0.60$	$\tau = 0.70$	$\tau = 0.80$	$\tau = 0.90$	$\tau = 0.95$
<i>Error correction term</i>											
$\xi(\tau)$	-0.729*** (0.103)	-0.640** (0.260)	-0.650** (0.278)	-0.419 (0.262)	-0.459* (0.270)	-0.397 (0.248)	-0.417* (0.222)	-0.554* (0.312)	-0.562* (0.306)	-0.571* (0.307)	-0.580* (0.307)
<i>Long-run estimates</i>											
$\beta_{gdp^s}(\tau)$	0.515*** (0.0770)	0.407** (0.185)	0.53*** (0.194)	0.467* (0.257)	0.490* (0.286)	0.505* (0.191)	0.377 (0.366)	0.422** (0.340)	0.347 (0.390)	0.383 (0.412)	0.425* (0.413)
$\beta_{gdp^2}(\tau)$	-0.0237*** (0.00378)	-0.018 (0.122)	-0.025** (0.017)	-0.021 (0.165)	-0.023*** (0.011)	-0.024* (0.012)	-0.167 (0.051)	-0.019 (0.013)	-0.015 (0.143)	-0.017 (0.016)	-0.019 (0.015)
$\beta_{ind^s}(\tau)$	0.0602*** (0.0167)	-0.0067 (0.039)	0.001 (0.029)	-0.021 (0.072)	0.024 (0.061)	0.047 (0.094)	0.042 (0.088)	0.057 (0.071)	0.018 (0.069)	0.025 (0.072)	0.032 (0.069)
$\beta_{unb^s}(\tau)$	-1.091*** (0.0822)	-1.05*** (0.115)	-1.07*** (0.102)	-1.10*** (0.154)	-1.08*** (0.131)	-1.05*** (0.156)	-0.95*** (0.277)	-0.98*** (0.242)	-1.04*** (0.207)	-1.18*** (0.196)	-1.28*** (0.237)
$\beta_{agri^s}(\tau)$	0.0781** (0.0287)	-0.0013 (0.095)	0.023 (0.094)	0.0274 (0.138)	0.059 (0.125)	0.064 (0.184)	0.074 (0.180)	0.090 (0.134)	0.011 (0.131)	0.040 (0.138)	0.087 (0.128)
$\beta_{open^s}(\tau)$	-0.0138*** (0.00343)	0.002 (0.008)	-0.01 (0.008)	0.004 (0.014)	-0.006 (0.013)	-0.009 (0.012)	-0.003 (0.010)	-0.009 (0.007)	-0.006 (0.007)	-0.009 (0.008)	-0.011 (0.008)
<i>Short-run estimates</i>											
$\phi_{1gdp^s}(\tau)$	0.571*** (0.0953)	0.663** (0.314)	0.650** (0.237)	0.547** (0.254)	0.532* (0.269)	0.521* (0.302)	0.969*** (0.317)	0.970*** (0.324)	0.846** (0.344)	0.891* (0.441)	0.949** (0.442)
$\gamma_{1gdp^s}(\tau)$	0.843** (0.332)	1.204 (0.894)	1.268 (0.829)	0.261 (1.107)	-0.0220 (1.316)	0.223 (1.439)	0.334 (1.332)	0.384 (0.996)	0.785 (1.139)	0.809 (1.166)	0.747 (1.166)
$\omega_{1gdp^s}^{sup}(\tau)$	-0.04333** (0.0168)	-0.0613 (0.0455)	-0.0642 (0.0422)	-0.0131 (0.0552)	0.00122 (0.0651)	-0.0115 (0.0714)	-0.0173 (0.0664)	-0.0199 (0.0505)	-0.0407 (0.0574)	-0.0415 (0.0585)	-0.0375 (0.058)
$\theta_{1agri^s}(\tau)$	-0.0195 (0.0137)	0.00542 (0.0413)	0.0171 (0.0400)	0.0122 (0.0382)	0.0148 (0.0414)	0.00853 (0.0480)	0.00810 (0.0511)	0.0159 (0.0756)	-0.0004 (0.0868)	0.00934 (0.0896)	0.0236 (0.089)

Table 5 (continued)

Parameters	ARDL ^(a) Quantile ARDL										
	$\tau = 0.05$	$\tau = 0.10$	$\tau = 0.20$	$\tau = 0.30$	$\tau = 0.40$	$\tau = 0.50$	$\tau = 0.60$	$\tau = 0.70$	$\tau = 0.80$	$\tau = 0.90$	$\tau = 0.95$
$\alpha_0(\tau)$	-1.403*** (0.355)	-0.879 (0.641)	-1.276*** (0.602)	-0.686 (0.684)	-0.806 (0.790)	-0.738 (0.847)	-0.547 (0.822)	-0.849 (0.997)	-0.611 (1.116)	-0.693 (1.169)	-0.811 (1.173)
Observations	41	41	41	41	41	41	41	41	41	41	41

Parentheses contain the standard errors

***, ** and * indicate significance at 1%, 5%, and 10% levels, respectively

^a The Akaike Information Criterion (AIC) is used to find the optimal lag lengths in the ARDL model, and these lengths are applied in the QARDL model. Diagnostic check for the ARDL model: Jarque–Bera 0.578 [0.748], cumulative sum test for parameter stability 0.601 [0.827], Breusch–Godfrey LM test for autocorrelation 1.637 [0.213], Ramsey RESET test 0.12 [0.5234], and Breusch–Pagan/Cook–Weisberg test for heteroskedasticity 0.07 [0.842] where all numbers in square brackets refer to the *p* value

will turn into an improvement path during later economic growth stages. In Egypt, linear ARDL results also indicate that urbanization is the most affecting variable on income inequality in the long run. An increase in urbanization by 1% reduces income inequality by 1.09% in the long run, but this effect has disappeared in the short run. Linear ARDL results also indicate that industrialization increases inequality. This effect is low in the long run (a 1% increase in industrialization leads to a 0.06% increase in the Gini coefficient) and does not exist in the short run. Although an increase in the share of agriculture in value added by 1% reduces income inequality during the short term by 0.01%, it leads to a deterioration of the Gini coefficient in the long run by 0.07%. Finally, openness has an improving effect on income distribution in the long run without any distributional effect in the short run.

4.3 Asymmetric cointegration results

Despite the importance of the linear ARDL results in exploring the cointegration relationships, this approach assumes that the effect of the model's independent variables on income inequality is linear in both long and short runs. It also assumes that the error correction term and then the model's speed in returning to the long-run equilibrium path does not change at different locations or quantiles of income inequality. This assumption may be valid if we reject the potential asymmetric relationship in the model. To confirm or refuse the linearity of the relationship between the model variables, Eq. (4) is estimated, and both Table 5 and Fig. 3 present the results of the QARDL model.

The same lag order specified in the ARDL guided by the AIC is used to estimate the QARDL model. Results show that the error correction terms in different quantiles, $\xi(\tau)$, are negative and significant in all locations except for the 0.3th and 0.50th quantiles. Moreover, the error correction process differs in its speed of adjustment according to the conditional distribution of the response variable. Compared with middle and high quantiles, the speed of adjustment is relatively faster in low quantiles, where the errors are corrected at a rate of 64 to 65% per year. This speed decreases in the middle quantiles to range between 39.7 and 45.9%, whereas the model's ability in removing its short-run disequilibrium to catch up long-run equilibrium path increases to a range between 55.4 and 58% in high quantiles. These different speeds of the adjustment process across different quantiles are confirmed by the Wald test results reported in Table 6. The null hypothesis of parameter constancy is highly rejected for $\xi(\tau)$, which implies that the adjustment speed in correcting disequilibrium in the short run is quantile dependent. This result supports our view that the distributional effects of economic growth and structural change variables in Egypt should be analyzed in an asymmetric rather than linear framework.

Although the results of the linear ARDL confirmed significant distributional effects of all variables, in the long run, the results of the QARDL reported in Table 5 are different and raise several points that need to be explained. First, estimates of QARDL show that Kuznets' inverted U-shaped relationship between growth and inequality is fulfilled significantly only across the lower half of the quantiles. Signs of both $\beta_{\text{gdp}^*}(\tau)$ and $\beta_{\text{gdp}^{2*}}(\tau)$ are significantly positive and

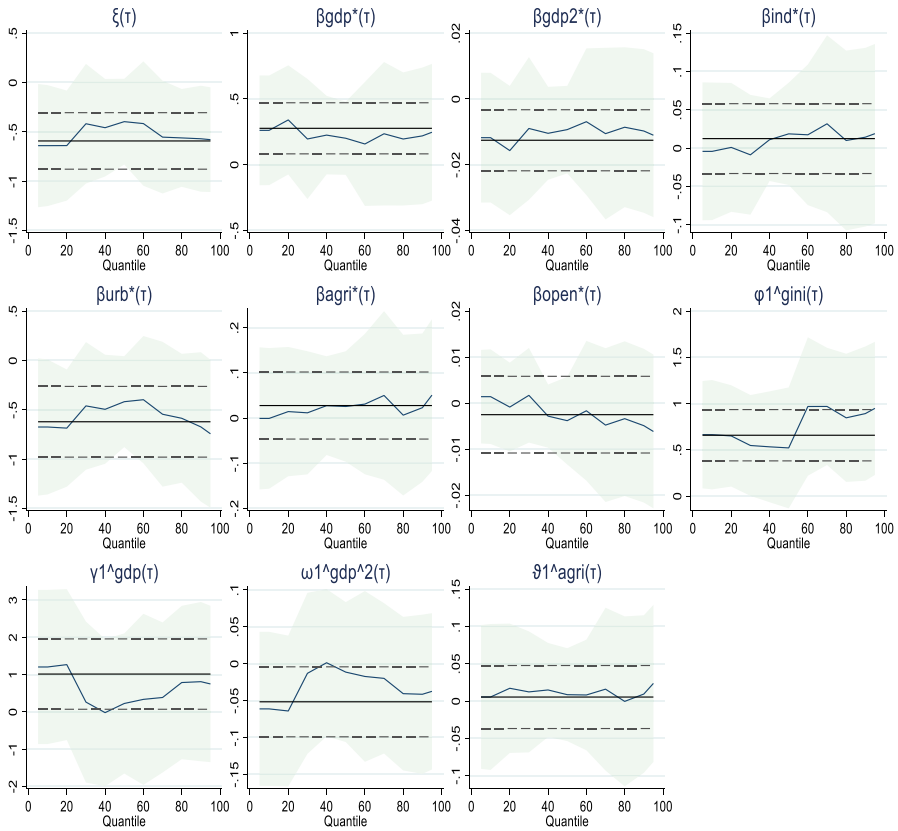


Fig. 3 Estimates of parameters behavior across different quantiles

negative, respectively, whereas no evidence is found to support the Kuznets’ hypothesis when the Gini coefficient is located at the upper half of quantiles. This means that economic growth does not affect high levels of income inequality according to the path defined by the Kuznets hypothesis, while the Kuznets hypothesis is valid only at low levels of income inequality, specifically when the Gini coefficient is located within the lower half of quantiles. As a result, economic growth will reduce inequality in advanced stages of development for low half quantiles but has no significant effect on income distribution for upper half quantiles in Egypt. This result was not clear in this way according to the reported estimates of the linear ARDL results in Table 5 while the QARDL estimates highlighted that this hypothesis applies only for the lower half quantiles in Egypt in the long run. This result is consistent, to a large extent, with some developments in both poverty rates and income distribution evolution among the wealthy groups in Egypt in recent years. As noted by some World Bank studies, economic growth besides fiscal policies has reduced poverty in Egypt after 2012/2013 (World Bank 2019), which is confirmed by our results. At the same time, income

Table 6 Wald test of parameter constancy

Parameters	<i>F</i> -statistic
$\xi(\tau)$	4.31*** (0.000)
$\beta_{\text{gdp}}(\tau)$	1.14* (0.056)
$\beta_{\text{gdp}^2}(\tau)$	3.02*** (0.009)
$\beta_{\text{ind}}(\tau)$	2.93** (0.011)
$\beta_{\text{urb}}(\tau)$	2.26** (0.0802)
$\beta_{\text{agri}}(\tau)$	1.91* (0.084)
$\beta_{\text{open}}(\tau)$	2.91** (0.012)
$\varphi_1^{\text{gini}}(\tau)$	8.37*** (0.000)
$\gamma_1^{\text{gdp}}(\tau)$	3.95*** (0.002)
$\omega_1^{\text{gdp}^2}(\tau)$	3.16*** (0.008)
$\vartheta_1^{\text{agri}}(\tau)$	2.47 (0.217)

Numbers between brackets are the *p* values

***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively

inequality within wealthy classes has been increased according to the World Bank data on poverty and equity. During the period 2010–2017, the income share of the upper 10% population in Egypt has increased from 24.8 to 26.9%, whereas the total share of the upper 20% has ranged between 40.1 and 41% (World Bank 2021). This implies more income concentration in the hands of rich classes, and that economic growth in Egypt does not have any significant effect in reducing inequality across rich classes as captured by our results.

Second, urbanization is the most variable that reduces income inequality in Egypt, as it has a significant effect that reduces the Gini coefficient in all quantiles, and this is consistent with the results of the linear model, but its effect is very strong in the high extreme quantiles, 0.90th, 0.95th. A 1% increase in urbanization ratio reduces income inequality by 1.18%, 1.28%, respectively, compared with 1.05 to 1.1% in low quantiles. This means that the effect of urbanization on reducing income inequality is higher when the Gini coefficient is in the upper quantiles compared with the lower and middle quantiles. The improving and strong impact of urbanization on reducing income inequality in Egypt has been also in other countries in some recent empirical studies like Padhan et al. (2020), Stiglitz (1969) and Wan et al. (2022) while contradicting the results of other

studies that have confirmed the worsening distributional impact of urbanization on other middle and low-income countries (Chen et al. 2016; Kanbur and Zhuang 2013; Sulemana et al. 2019). But in the case of Egypt, it is possible to explain the strong role of urbanization in reducing income inequality in Egypt as a result of the large income gap between urban and rural in favor of the urban (Adams and Page 2003; Korayem 1981); therefore, any increase in the rate of urbanization resulted from economic growth processes will have a significant impact on reducing the overall income inequality in Egypt. The third point noted in the long-run results of the QARDL is the insignificant distributional effects of industrialization, agriculture, and openness across all quantiles. Industrialization had a bad effect on income inequality, except for the lower two quantiles, but it is not significant in all quantiles. This result contrasts with the significant worsening distributional effect of industrialization found in the linear ARDL estimates reported in Table 6. But looking at the value of the estimated industrialization coefficient according to the linear ARDL model, we find that it is very small, an increase in industrialization value added in the total value added by 1% leads to an increase in the Gini coefficient by only 0.06% in the long run. This analysis is relevant also in the cases of both agriculture and openness as shown in the small distributional effects of them in the long run.

For the short-run behavior of the model, estimates of QARDL show that past values of the first difference income inequality captured by $\varphi_1^{\text{gini}}(\tau)$ lead to a significant increase in the Gini coefficient. These deteriorated effects are significant at all quantiles and become stronger in high quantiles compared with other middle and low quantiles. This means that inequality leads to more inequality in Egypt during the short run. This result is consistent with failure in capturing the existence of Kuznets inverted U-curve in Egypt during the short run where the coefficients $\gamma_1^{\text{gdp}}(\tau)$ and $\omega_1^{\text{gdp}}(\tau)$ are insignificant across all quantiles. Though the parameter constancy hypothesis is rejected for $\gamma_1^{\text{gdp}}(\tau)$ and $\omega_1^{\text{gdp}}(\tau)$. The same applies to the absence of a significant effect of agriculture on income inequality in the short run. Finally, the results of the Wald test for parameter constancy in Table 6 support rejecting the symmetry hypothesis for all parameters except for agricultural coefficients in the short run. This indicates that there is an asymmetry in the effect of the study variables on the income inequality in Egypt across the different quantiles.

5 Conclusion and policy implication

Considering the Egyptian economy's multiple attempts to get out of the middle-income countries trap that many developing economies suffer from, and move to the ranks of developed countries, there is a need to analyze the distributional effects of both economic growth and structural changes that accompanied economic development path in Egypt during the previous four decades. Many empirical studies did not consider the effect of structural changes when analyzing the drivers of income inequality. In this context, the current study highlights the importance of augmenting the structural changes accompanying economic development policies to capture a more comprehensive picture of the determinants

of income inequality in Egypt. To complete the picture, the current study also investigates the impact of both economic growth and structural changes in an asymmetric framework depending on newly econometric techniques that analyze the relationship between variables in an asymmetric and nonlinear framework rather than assuming symmetry. The QARDL methodology developed by Cho et al. (2015) is employed to explore potential asymmetric quantile cointegration between income inequality, economic growth, and structural changes proxied by the evolution of industrialization, urbanization, in addition to the percentage of both agriculture and foreign trade in GDP over the period 1975–2017. Results confirm an asymmetric cointegration between these variables. There is a long-run equilibrium relationship between income inequality, economic growth, and structural changes in Egypt. Speeds of adjustment to catch up with the long-run equilibrium path differ significantly across different quantiles to support the asymmetric behavior. While the disequilibrium is corrected in the short run at a speed of 65 to 64% for the lower quantiles, this correction process slows down to reach 55 to 58% at the upper locations of the Gini coefficient.

Egypt must take care of reducing income inequality as this will support economic growth. To achieve this, it must run different income redistribution policies through fiscal policy. As the results indicated, urbanization has a significant impact in reducing income inequality in the long run across all locations of the Gini index. Thus, the adoption of policies that increase urbanization will contribute significantly to reducing inequality in Egypt in the long run. The infeasibility of depending on fiscal policies in developing countries (Wan et al. 2022), including Egypt, to redistribute income and reduce inequality due to the weak financing capabilities and the permanent and structural budget deficits, accelerating urbanization rates is the most appropriate in reducing inequality in Egypt.

Results also indicated an important finding in which the Kuznets hypothesis is valid only when the Gini coefficient of income inequality is located at the lower half of income inequality quantiles, while it is not working in the upper half of the quantiles. This result is very important in guiding economic policymakers in Egypt and urging them to reduce inequality under its current levels so that the inverted U-shaped curve can be worked, and economic growth can be effective in reducing inequality in the long run.

There are several limits in handling the results of the study. The previous analysis did not address the impact of some potentially important variables that may contribute to explaining the decline in growth rates and related to income inequality at the same time, such as monitoring the impact of inequality on human development, and the impact of inequality on productivity in Egypt during the previous decades. Moreover, it remains said that the results of this study depend on the income inequality indicator that has been used, the Gini coefficient. So, it is possible that we may obtain results that contradict or agree with the results of our study if other indicators of inequality are used, such as the income share of the richest 10% of the population compared to the share of the poorest 40%; however, this remains subject to the availability of data in Egypt.

Declarations

Conflict of interest The author declares that he has no competing interests.

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