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The Impact of Digitalization and Globalization on Income Distribution in Emerging Industrial Economies[*]

Yükselen Sanayi Ekonomilerinde Dijitalleşme ve Küreselleşmenin Gelir Dağılımı Üzerindeki Etkisi

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Abstract: Digitalization is one of the most important indicators of technological development. More specifically, digitalization affects income distribution in different ways. Improvement in digital technologies promotes labor productivity and economic efficiency. Hence, how digitalization affects income inequality is required to obtain more evidence. This study investigates the distributional impact of digitalization in 29 Emerging Industrial Economies (EIEs) over the period 2000-2020. The cross-sectionally augmented autoregressive distributed lag (CS-ARDL) estimation results show that digitalization and globalization alleviate income inequality. Likewise, economic growth negatively affects income inequality. In contrast, political stability has a positive impact on income inequality. Moreover, the Dumitrescu-Hurlin (D-H) panel causality test result confirms the two-way causality between economic growth, globalization, political stability, and digitalization with income inequality.

Keywords: Digitalization, Income Inequality, Globalization, Emerging Industrial Economies, CS-ARDL

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Öz: Dijitalleşme, teknolojik gelişmenin en önemli göstergelerinden birisidir. Daha spesifik olarak, dijitalleşme gelir dağılımını farklı şekillerde etkilemektedir. Dijital teknolojilerdeki gelişme işgücü verimliliğini ve ekonomik etkinliği artırmaktadır. Bu nedenle, dijitalleşmenin gelir eşitsizliğini nasıl etkilediğine dair daha fazla kanıt elde edilmesi gerekmektedir. Bu çalışma, 2000-2020 dönemi için 29 Yükselen Sanayi Ekonomisinde (EIEs) dijitalleşmenin dağılımsal etkisini araştırmaktadır. Kesitsel olarak genişletilmiş gecikmesi dağıtılmış otoregresif (CS-ARDL) tahmin sonuçları, dijitalleşmenin ve küreselleşmenin gelir eşitsizliğini azalttığını göstermektedir. Benzer şekilde, ekonomik büyüme de gelir eşitsizliğini negatif etkilemektedir. Buna karşılık, politik istikrar gelir eşitsizliği üzerinde pozitif etkiye sahiptir. Ayrıca, Dumitrescu-Hurlin (D-H) panel nedensellik testi sonucu ekonomik büyüme, küreselleşme, politik istikrar ve dijitalleşme ile gelir eşitsizliği arasında iki yönlü nedensellik ilişkisinin olduğunu doğrulamaktadır.

Anahtar Kelimeler: Dijitalleşme, Gelir Eşitsizliği, Küreselleşme, Yükselen Sanayi Ekonomileri, CS-ARDL

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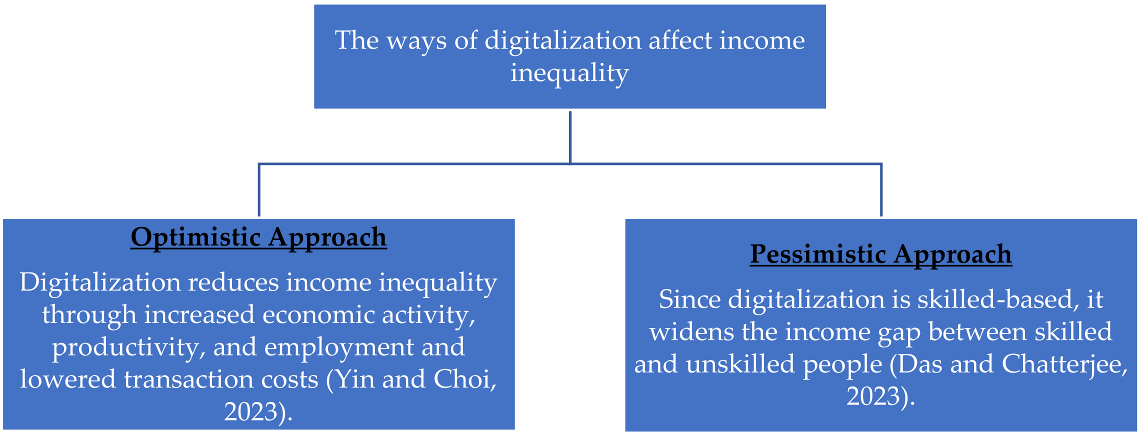
1. Introduction

In the 21st century, digitalization rapidly shapes and transforms our world. Digitalization represents that digital technologies have a remarkable and dominant role in the economy (Namazi, 2020). In addition to robots and machines, technological improvements now also include software and artificial intelligence (AI), which significantly impact labor structure (Fiedler et al., 2021). The emergence of AI, robotics tools, and information and communication technologies (ICTs) are driving digital transformation (Huang et al., 2023). ICTs have become one of the most crucial factors influencing economic performance and social development (Habibi and Zabardast, 2020).

There exist tremendous analyses in the literature investigating the relationship between digitalization and economic growth (Aleksandrova et al., 2022; Brodny and Tutak, 2022; Habibi and Zabardast, 2020; Myovella et al., 2020; Wu and Yu, 2022; Zhang et al., 2022). It is argued that digitalization can lead to lower transaction costs and improved efficiency in the market, which in turn can boost productivity for both labor and capital. This increased productivity is a key factor in fostering economic growth (Aleksandrova et al., 2022). For instance, ICTs to incentivize e-commerce have increased financial activity while keeping transaction costs low, making it easier to access a large bundle of goods and services through digital channels (Habibi and Zabardast, 2020). The relationship between digitalization and economic growth is closely linked. However, some ambiguity surrounds the connection between digitalization and income inequality. In other words, while digitalization affects economic growth through various ways, there is a correlation between digitalization and income inequality. Researchers suggest that digitalization can improve economic activities, boost productivity, and offer low-cost financial tools for low-income individuals. Furthermore, digitalization is expected to enhance the skills of workers and create new opportunities for knowledge acquisition (Nguyen, 2022; Nguyen, 2023). In particular, digital financialization provides affordable credit facilities and financial instruments in rural areas, which can help close the income gap and reduce income inequality (Yao and Ma, 2022). In addition, digital technologies have reduced the disadvantages of trade distances between regions, resulting in increased integration both within and between international regions. This reduction in trade distances has opened up opportunities for labor and firms to benefit from networks (UNCTAD, 2023).

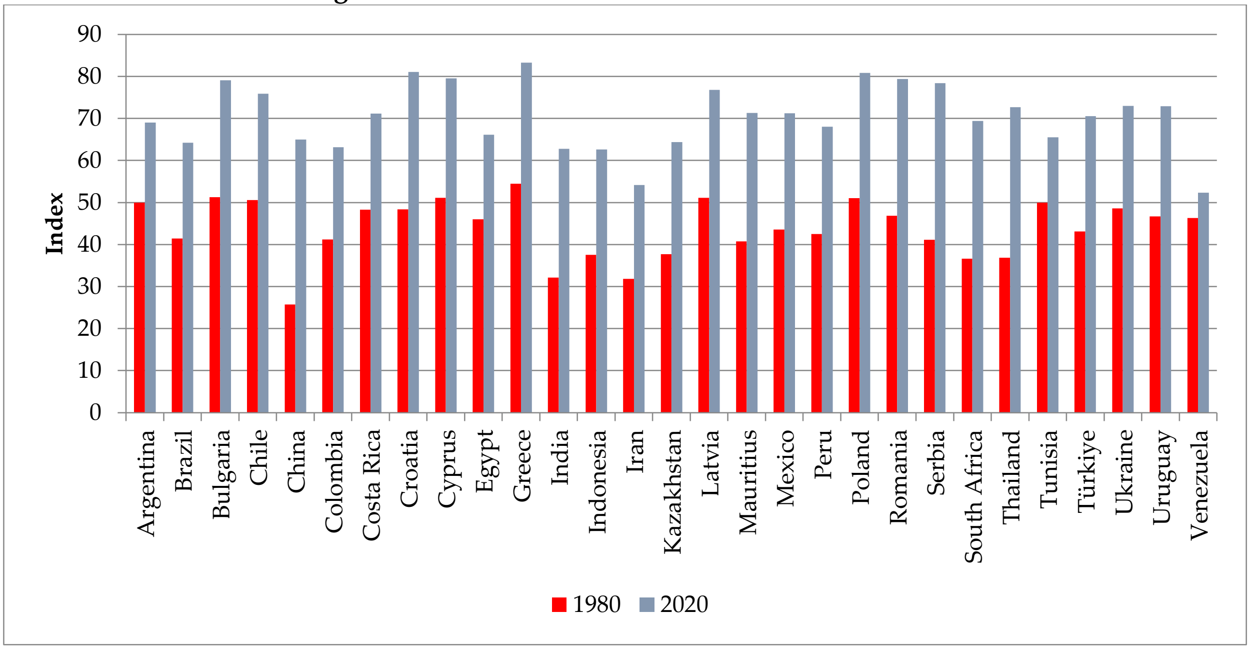
Figure 1: The Relationship between Digitalization and Income Inequality



Source: Authors' compilation.

In contrast, digitalization can increase income inequality. Because in the age of digitalization, technological developments are mainly skilled-based, and it requires having a set of financial literacy. Therefore, digitalization constrains unskilled people from accessing digital economic instruments and increases inequality across unskilled and skilled labor (Das and Chatterjee, 2023). Despite the significant improvement in digitalization, the digital division is still a crucial problem. A huge gap exists between developed and less developed countries (LDCs). According to the UNCTAD (2021) report, 23% of the total population in the LDCs have no access to mobile broadband networks, and the average internet speed of developed countries is eight times higher than LDCs. Furthermore, inequality remains a significant global issue in both developed and developing nations. Even though there was a slight improvement in global income inequalities, the inequalities within countries have risen. For example, the income gap between the top 10% and the bottom 50% increased eight to 15 times from 1980 to 2020. In this framework, our paper examines the effect of digitalization and globalization on income inequality in 29 Emerging Industrial Economies (EIEs) (Argentina, Brazil, Bulgaria, Chile, China, Colombia, Costa Rica, Croatia, Cyprus, Egypt, Greece, India, Indonesia, Iran, Kazakhstan, Latvia, Mauritius, Mexico, Peru, Poland, Romania, Serbia, South Africa, Thailand, Tunisia, Türkiye, Ukraine, Uruguay, and Venezuela) over the period 2000-2020.

Figure 2. KOF Globalization Index in the EIEs

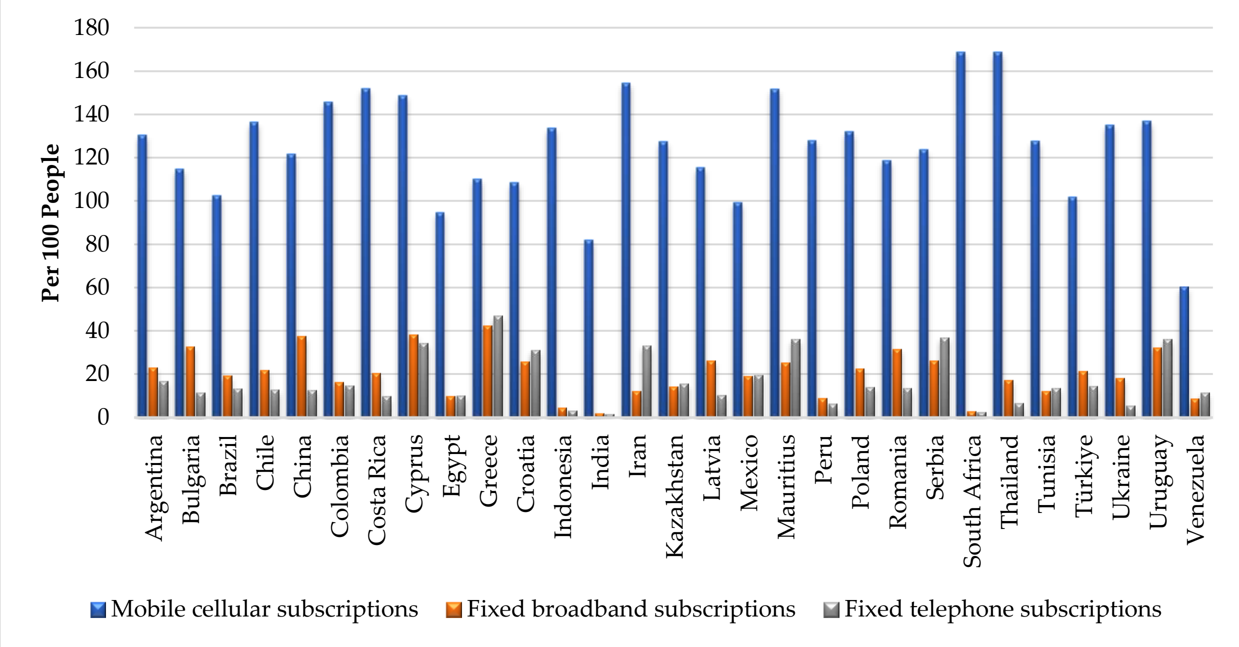


Source: Authors' compilation based on Gygli et al. (2019) data

Integrating the world economy is one of the important properties of the EIEs. Under the globalization policies, most developing countries have gradually liberalized their economy since the 1980s. As depicted in Figure 2, globalization[4] remarkably increased in all EIEs. Since globalization surrounds all developing countries, it exposes countries to external shocks and instabilities.

[4] In Figure 2, due to the lack of data, the KOF globalization index data for Croatia, Kazakhstan, Latvia, and Ukraine belongs to 1995.

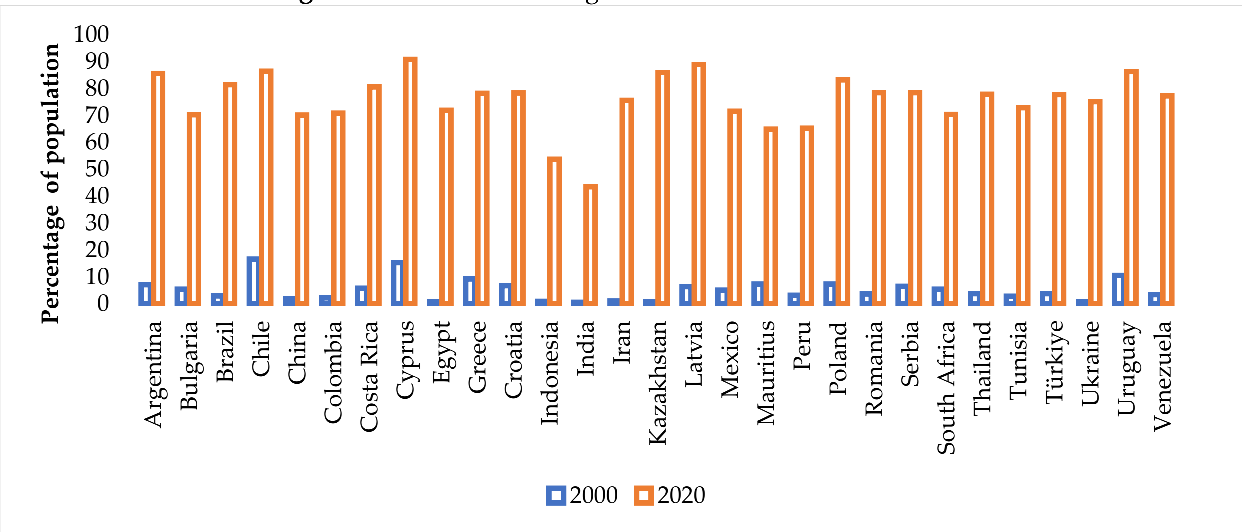
Figure 3: Components of Digitalization in the EIEs as of 2021



Source: Authors' compilation based on World Bank (2023) data

Since the 2000s, the EIEs have experienced significant growth, with a continued push towards digitalization. Figure 3 shows the various components of digitalization within these countries, with mobile cellular subscriptions being the largest aspect. South Africa, Thailand, Iran, and Costa Rica boast the highest mobile cellular subscriptions per 100 individuals, while Venezuela has the lowest level. Fixed broadband and telephone subscriptions are lower than mobile cellular subscriptions. This discrepancy is not surprising, as mobile internet has rapidly transformed the economic and social life of developing countries (UNCTAD, 2023). As a result, using the internet has significantly increased in the EIEs.

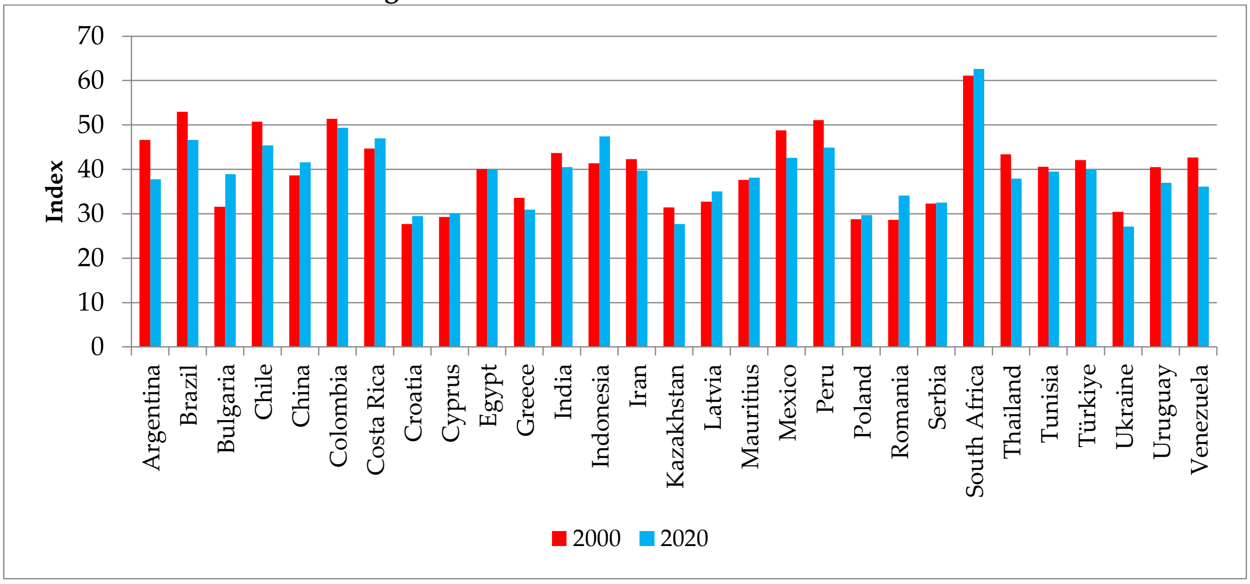
Figure 4: Individuals Using the Internet in the EIEs



Source: Authors' compilation based on World Bank (2023) data

As depicted in Figure 4[5], using the internet rate has risen in the EIEs over 2000-2020. In 2000, the using the internet rate was very low. However, improvement in digital technologies has continuously triggered an increase in using the internet. In 2020, the largest internet use share belongs to Cyprus, with more than 90% of the population, followed by Latvia, Uruguay, Kazakhstan, and Poland. The lowest rate is in India, thanks to its huge population. Next to the digitalization process, income inequality is still one of the crucial issues for developing countries.

Figure 5: Gini Coefficient[6] in the EIEs



Source: Authors' compilation based on Solt (2020) data

The EIEs have an important feature regarding income inequality. Although some countries have seen a decline in inequality, it still remains high and significant. Inequality has reduced in Argentina, Brazil, Chile, Colombia, Egypt, Greece, India, Iran, Kazakhstan, Mexico, Peru, Thailand, Tunisia, Türkiye, Ukraine, Uruguay, and Venezuela. However, Bulgaria, China, Costa Rica, Croatia, Cyprus, Indonesia, Latvia, Mauritius, Poland, Romania, Serbia, and South Africa have experienced a worsening of inequality from 2000 to 2020. Essentially, there has been no noteworthy improvement in income distribution in the EIEs over the past two decades. As per Figure 5, South Africa has the worst income distribution, with a Gini index of 62.6 in 2020, followed by Colombia at 49.4, Indonesia at 47.4, and Brazil at 46.6.

In the scope of explanation mentioned above, it is crucial to assess the relationship between digitalization and income inequality in the EIEs. This paper contributes to the existing literature in three ways: i) To the best of the authors' knowledge, it is first to analyze the distributional impact of digitalization in the EIEs; ii) We calculated the information and communication technologies (ICTs) index using different indicators through principal component analysis (PCA). Therefore, a composed ICT index is utilized as a proxy for digitalization instead of a single indicator; iii) We aim to explore the effect of globalization on digitalization; iv) We perform the second-generation estimation strategy that takes into account cross-sectional dependence.

The rest of the paper is structured in the following ways: Section 2 explains the concept of income inequality, Section 3 summarizes the literature review, and Section 4 describes the data, model, and

[5] According to the World Bank (2023), the data for Serbia starts from 2004 and Venezuela ends in 2017. Hence, the missing data completed by employing the interpolation technique.

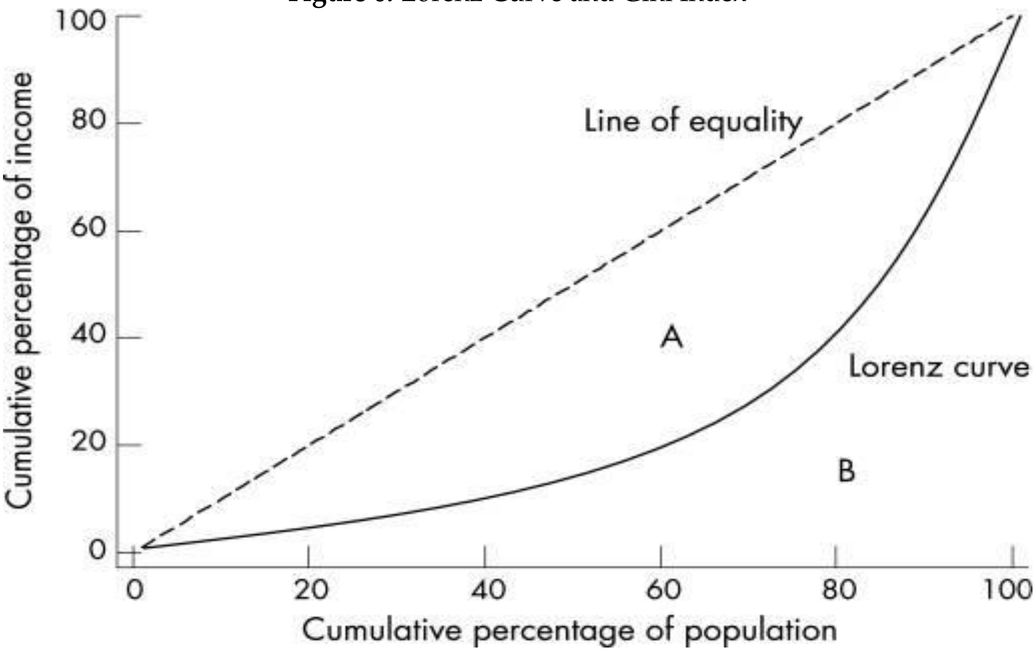
[6] According to the Solt (2020) data, the latest Gini index for Egypt is available in 2017, Iran in 2018, Mauritius in 2017, Serbia in 2019, South Africa in 2017, Tunisia in 2015, and Ukraine in 2019. The missing data is completed by employing the interpolation technique. Thus, the Gini index of Egypt, Iran, Mauritius, Serbia, South Africa, Tunisia, and Ukraine for 2020 represents data obtained from the interpolation technique.

estimation strategy. Section 5 presents empirical findings, and Section 6 provides conclusions and policy implications based on empirical findings.

2. The Concept of Income Inequality

Income inequality is a significant aspect of income distribution. Although the classification and measurement of income inequality can be complex, there is a consensus that income inequality refers to the uneven distribution of income among individuals or households (Trapeznikova, 2019). Income covers different components, including self-employment income (wage, salary), capital income (comes from dividends or rent, interest), and government pensions (Trapeznikova, 2019; Brandolini and Smeeding, 2009). Milanovic (2006, 2012) defines three dimensions of income inequality in this framework. Based on his classification, Concept 1 represents income inequality among nations with their income levels (or gross domestic product) without weighted countries' population. Concept 2 denotes the inequality between countries with weighted countries' populations. Concept 3 represents global inequality, which considers global interpersonal inequality with individual assigned per capita income. Contrary to the first two concepts, in Concept 3, all individuals are taken into account with their actual income regardless of their country (Milanovic, 2012; Anand and Segal, 2008). In order to measure income inequality, there are different measurement tools: the Lorenz Curve, the Gini Index, the Theil Index, the Atkinson Index, decile ratios, and the Palma ratio (Trapeznikova, 2019; Manga and Cengiz, 2020). However, the Gini Index is commonly used to measure income inequality in the relevant literature.

Figure 6. Lorenz Curve and Gini Index



Source: De Maio, 2007: 850.

The Gini Index is derived from the Lorenz Curve. As depicted in Figure 6, the Lorenz Curve indicates the percentage of total income gained by the cumulative percentage of the total population. The curve of the line of equality with a 45^0 angle represents that the income is distributed equally. For example, the bottom 50% of the population earns 50% of the total income. However, the Lorenz curve moves from the equality line as income inequality increases. In this case, the income is unequally distributed in the country; for example, the bottom 50% of the population earns 25% of the total income. Based on the Lorenz Curve, the Gini index can be calculated. It is equal to the area between the Lorenz Curve and the equality line depicted with A in Figure 5, divided by the area under the equality line (45^0 angle) that is depicted with A+B. Thus, the Gini index equals A/(A+B) (De Maio, 2007). The Gini index (or coefficient) changes between 0 and 1. If the Gini coefficient is 0, the income is equally distributed in the economy. In contrast, A coefficient of 1 indicates that income is perfectly unequally distributed in the economy (De Maio, 2007; Milanovic, 2012).

3. Empirical Literature Review

Economic growth and development are significantly affected by technological advancements. Economies that can quickly catch up with technological developments can achieve substantial development and economic growth. In nations where knowledge, scientific methodologies, and innovations have come to the forefront, a discernible augmentation in productivity has been observed, concomitant with a corresponding upsurge in economic expansion (Nas, 2023). In this sense, it may be claimed that technological advancements, inventions, and innovations have helped to develop (Nas, 2021). In the post-1980 period, the spread of ICTs and the increase in knowledge-based production techniques enabled the rapid development of economies. Hence, akin to the transformative advancements witnessed during the Industrial Revolution, it can be contended that the accessibility to information activities and the adoption of digital techniques in production have augmented the gap between economies. Because using ICTs to produce goods and services makes an economy more competitive, boosts industrial output, and promotes increased labor skills. Thus, the crucial question of how increasing digitalization affects income inequality arose.

The nexus between ICTs and economic growth recently has garnered remarkable attention (Odhiambo, 2022). The primary cause of this is the use of digital technology as a necessity for economic activities and a key driver of economic expansion (Noh and Yoo, 2008). In addition, investments in ICTs and digitalization increase productivity by reducing costs (Asongu et al., 2023). Consequently, the strategic measures pursued in digitalization catalyse promoting innovative practices and, in the long run, play a pivotal role in fostering sustainable economic growth. Concurrently, the expansion of the ICTs can serve as a mitigating factor in alleviating income inequality within the economy (Afzal et al., 2022). Similarly, Chipeva et al. (2018) emphasize that investing in ICTs yields substantial economic benefits, enhances productivity, lowers costs, promotes innovation, and facilitates trade. Also, Guellec and Paunov (2017) posit that an upsurge in digital innovation results in market share expansion, thereby favoring higher-income groups. According to the authors, digital innovation leads to the expansion of market power. Therefore, it is only possible for markets with digital competition to benefit from cost advantages. As a result, income inequality between nations increases. Consequently, the escalation of digital inequalities causes significant economic challenges.

There is a growing body of literature investigating digitalization and economic growth (Ali et al., 2019; Li et al., 2023; Shah and Krishnan, 2023; Wang and Xu, 2023). For instance, Tchamyou et al. (2018), in their analysis of 48 African countries for 1996-2014, stated that ICTs reduce income inequality in the financial sector. Asongu and Odhiambo (2019) also applied the system GMM for 2004-2014 for 48 African countries. The GMM analysis findings indicate that digitalization reduces income inequality. In their study conducted for 35 Sub-Saharan African countries using the Finite Mixture Model (FMM), Ndoya and Asongu (2022) suggest that in the period 2004-2016, digital inequality had a negative effect on income inequality, especially in countries with high globalization tendency, while digital inequality has a positive impact on income inequality in countries with low globalization level. Awad (2022) asserts that the expansion of ICTs positively affects poverty levels in 37 Sub-Saharan African countries. Dzator et al. (2023) researched the relationship between digitalization and poverty in Sub-Saharan African countries over the period 2010-2019 by using a system and GMM estimator. According to the results, telephone penetration, mobile phone penetration, and imported ICT products reduce poverty, whereas internet penetration, broadband penetration, and exported ICT products increase poverty. Similarly, Dossou et al. (2023) also applied the system GMM to investigate the association between ICTs and income distribution in 42 Sub-Saharan African countries for the period 1996-2020 by performing a GMM estimator. They found that ICTs positively affect income distribution. Richmond and Triplett (2018) investigated the relationship between digitalization and income inequality for a panel sample of 109 countries from 2001 to 2014. They concluded that fixed broadband subscriptions increase income inequality while mobile subscriptions decrease income inequality. In their study for Indonesia, Untari et al. (2019) state that investments in ICTs from 2011 to 2016 positively affected economic growth and indirectly positively affected income inequality. Fiedler et al. (2021) examined the relationship between robot density and the Gini coefficient in Western European countries. According to their findings, a 1% increase in robot density in 2005-2017 increased the Gini coefficient by 4.2%, while ICT did not affect inequality.

Nguyen (2022) applied the GMM and PMG estimators for developed and developing countries for the period 2002-2020. According to the author's findings, while digitalization narrows inequality in developed economies, it widens it in developing economies. Yao and Ma (2022) investigated the relationship between digital finance and income inequality in China's regions over the period 2011-2020. Their empirical findings show an inverted U-shaped relationship between digital finance and inequality.

Patria and Erumban (2020) researched the relationship between adopting ICTs and income inequality in Indonesian provinces from 2012-2016. Their empirical findings demonstrate the inverted U-shaped association between ICT adoption and income inequality, indicating that the beginning of ICT adoption causes a rise in income inequality. However, it decreases inequality in the latter stage. Houngbonon and Liang (2021) analyzed digitalization and income inequality in France. They used the broadband internet as a proxy for digitalization. The empirical findings documented that digitalization has a negative impact on income inequality. According to Adegboye et al. (2022), ICT adoption significantly affects inclusive human development in upper-middle-income nations. Deng et al. (2023), in their study of 202 cities in China for 2011-2019, argue that digitalization can improve the absolute income level in rural and urban areas. Das and Chatterjee (2023) emphasize that ICT diffusion reduces poverty in urban and rural areas of India. Nguyen (2023) studied the association between digitalization and income inequality by observing the role of FDI for 65 countries during the 2002-2019 period. The system GMM estimation results show that digitalization narrows income inequality in developed and developing countries. In contrast, the interaction of FDI and digitalization widens inequality in developing countries but decreases in developed countries. Yin and Choi (2023) investigated the impact of digitalization and globalization in the G-20 from 2002 to 2018. They found that digitalization and the interaction of digitalization and globalization negatively affect income inequality in the whole panel sample, but their impacts vary by income level. Jing et al. (2019) examined the impact of ICTs on income inequality for a panel sample of five ASEAN countries between 2009 and 2017 and found that ICTs narrow income inequality. Upon reviewing the literature, it is evident that more empirical findings are required to deepen our understanding of the relationship between digitalization and income inequality.

4. Data and Methodology

This section introduces the data, models, and empirical methodologies.

4.1. Data

This paper explores the dynamic nexus among economic growth, globalization, digitalization, and political stability, and income inequality in 29 EIEs over the period of 2000-2020. Following the work of Richmond and Triplett (2018), Demir et al. (2022), Yin and Choi (2023), Lee et al. (2022), and Zehra et al. (2021), we used Gini index as a proxy for income inequality.

The form of our theoretical model is as follows:

$$\mathrm{GIN_{it}} = \mathrm{f(GDP_{it}, DIG_{it}, POL_{it}, KOF_{it})} \qquad (1)$$

where GIN is the Gini index, GDP represents the per capita GDP, DIG refers to digitalization, which is measured using the information and communication index. This index is computed through principal component analysis (PCA), incorporating several the ICTs indicators such as the share of individuals using the internet, fixed broadband, telephone, and mobile cellular subscriptions. POL is the political stability index and KOF is the globalization index. An important point to be emphasized about the data set of the study is the following: Firstly, the missing data observed in the Gini coefficient index variable of some countries in the sample were produced by interpolation method using the SPSS program[7].

[7] These countries are, Egypt, Iran, Mauritius, Serbia, South Africa, Tunisia, and Ukraine.

Secondly, principal component analysis (PCA)[8] is a widely used approach when dealing with datasets that have a large number of dimensions or features per observation. It is an effective method for handling substantial datasets, as it enhances data interpretation by preserving the most relevant information and facilitates the representation of complex multidimensional data. In simpler terms, PCA is a statistical technique employed to reduce the dimensionality of datasets, which enhances their interpretability while minimizing the loss of essential information (Krishnan, 2010).

Eq. [1] has the following semi-natural logarithmic form:

$$\mathrm{lnGIN_{it}} = \beta_0 + \beta_1 \mathrm{lnGDP_{it}} + \beta_2 \mathrm{DIG_{it}} + \beta_3 \mathrm{POL_{it}} + \beta_4 \mathrm{lnKOF_{it}} + \mu_{it} \quad (2)$$

where β refers to coefficients, i donates period, t refers to cross-section, and μ_{it} is the error term.

Table 1: Variables and Data Sources

Variable	Description	Unit	Source
GIN	Income inequality	Index (0-100)	Solt (2020)
GDP	Economic growth	per capita (constant 2015 USA Dollars)	World Bank (2023)
KOF	Globalization	Index (1-100)	Gygli et al. (2019)
DIG	Digitalization	PCA based index	ITU (2023)
POL	Political Stability	Index (-2.5 weak; 2.5 strong)	The Global Economy (2023)

Note: ITU: International Telecommunication Unity.

4.2. Methodology

This study proceeds in four methodological steps. Firstly, a cross-sectional dependence (CSD) test is performed. Secondly, the cross-sectional augmented IPS (CIPS) unit root test is employed to detect stationarity. In the third step, the cross-sectionally augmented autoregressive distributed lag (CS-ARDL) to estimate long-run coefficients of our model. Finally, the D-H test is performed to determine causality relationships among variables.

4.2.1. The Cross-sectional Dependence (CSD) Test

The CSD is done using several tests, such as the Breusch and Pagan (1980) LM test, Pesaran (2004) CD test, and the bias-corrected scaled LM test proposed by Pesaran et al. (2008). However, the Breusch-Pagan (1980) LM test is not applicable when the CSD dimension is larger than the temporal dimension (N>T). In such cases, the Pesaran (2004) and Pesaran et al. (2008) CD tests can be used. The Breusch and Pagan (1980) LM test can be represented as follows:

$$y_{it} = \alpha_i + \beta_i x_{it} + \varepsilon_{it}\, , = 1, \ldots, N\, ,\, t = 1, \ldots, T \quad (3)$$

$$LM = T \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} P_{ij}^2 \quad (4)$$

The LM test statistic is based on two hypotheses. $H_0\colon C\,ov(\varepsilon_{it}, \varepsilon_{jt}) = 0$ (There is dependency between the countries included in the model.) ve $H_1\colon C\,ov(\varepsilon_{it}, \varepsilon_{jt}) \neq 0$ (There is no dependency between the countries included in the model.). The Pesaran (2004) CD_{LM} can be written as follows:

$$CD_{LM} = \sqrt{\left(\frac{1}{N(N-1)}\right) \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \left(TP_{ij}^2 - 1\right)} \quad (5)$$

In Eq. (5), if N>T, the $\mathrm{CD_{LM}}$ test shows level distortions, so Pesaran (2004) CD test is as follows:

[8] Pearson (1901) provided the first description of a method that is now known as PCA.

$$CD = \sqrt{\left(\frac{2T}{N(N-1)}\right)} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \left(\hat{P}_{ij} - 1\right) \quad (6)$$

The representation of the bias-corrected scaled LM test, introduced by Pesaran et al. (2008), is as follows, with 'k' indicating the number of regressors:

$$LM_{adj} = \sqrt{\left(\frac{2}{N(N-1)}\right)} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} P_{ij} \frac{(T-k)P_{ij}^2}{\sqrt{v_{T_{ij}}^2}} \quad (7)$$

4.2.2. The CIPS Panel Unit Root Test

In this stage, the CIPS test is applied to assess stationarity level of variables. The Pesaran (2007)'s CIPS unit root test can be calculated using the following equation:

$$CIPS = \frac{1}{N} \sum_{i=1}^{N} t_i(N,T) \quad (8)$$

4.2.3. The CS-ARDL Estimation Method

Our study employs the CS-ARDL developed by Chudik and Pesaran (2015) as an estimator to determine the long-run dynamic relationship between income inequality, economic growth, digitalization, political stability, and globalization. This method is robust to the CSD and considers the slope heterogeneity in the model (Chudik and Pesaran, 2015; Chudik et al., 2017; Mehmood, 2022) and allows to estimate in the case of mixed-order integration (Voumik et al., 2023). The CS-ARDL regression can be written as follows (Sharif et al., 2023):

$$X_{it} = \sum_{l=0}^{P_\alpha} \delta_{I,i} X_{i,t-1} + \sum_{l=0}^{P_\beta} \gamma_{I,i} Y_{i,t-1} + \sum_{l=0}^{P_\vartheta} \acute{\tau}_{i,} I \overline{K}_{i,t-1} + \varepsilon_{i,t} \quad (9)$$

where $\overline{K}_{i,t-1}$= ($X_{i,t-1}$, $Y_{i,t-1}$), P_α, P_β, and P_ϑ denote the lags of each factor. Furthermore, X_{it} represents the dependent variable (GIN), and $Y_{i,t}$ denotes a set of independent variables: economic growth (GDP), globalization (KOF), digitalization (DIG), and political stability (POL). Also, $\overline{K}$ shows average of the CD.

In the CS-ARDL estimation technique, the long-run value is estimated from the coefficients of short-term correlation. Hence, long-run coefficient and mean group estimator (MG) estimations are as follows (Jian and Afshan, 2023; Okumus et al., 2021):

$$\hat{\theta}_{CS-ARDL,i} = \frac{\sum_{l=0}^{P_\alpha} \hat{\delta}_{l,i}}{1 - \sum_{l=0}^{P_\beta} \hat{\gamma}_{l,i}} \quad (10)$$

$$\hat{\theta}_{MG} = N^{-1} \sum_{i=1}^{N} \hat{\theta}_i \quad (11)$$

4.2.4. The Dumitrescu-Hurlin (D-H) Panel Causality Test

The fourth phase of our analysis involves unveiling the possible causal association among variables. Thus, we performed D-H panel causality test to examine the long-term relationships between economic development, digitalization, institutional quality, globalization, and income inequality. We estimate causality tests, which, when applied to panel data, can be visualized as bivariate regressions, as a robustness test. We will use the Granger non-causality approach to reason using panel data. The typical Granger test makes the assumption that all of the panel members' coefficients are comparable (Mabrouki, 2022). D-H test makes the assumption that the coefficients vary depending on the cross sections. The D-H test is defined as follows in the specification proposed by Dumitrescu-Hurlin (2012):

$$y_{it} = \alpha_i + \sum_{i=1}^{K} \gamma_i^k y_{i,t-k} + \sum_{i=1}^{K} \beta_i^k x_{i,t-k} + \varepsilon_{it} \tag{12}$$

In Eq. [12], α_i represents the cross-sectional units, K stands for the lag length, t represents the time period, and β_i^k represents the slope coefficients. In the D-H test procedure, the alternative hypothesis proposes the existence of a causal relationship in at least one cross-sectional unit, whereas the null hypothesis states no causation in the panel. To test the null hypothesis, the following statistics are employed (Çetin et al., 2023):

$$\bar{W} = \frac{1}{N}\sum_{i=1}^{N} W_i \tag{13}$$

$$\bar{Z} = \sqrt{\frac{N}{2K}}(\bar{W} - K) \tag{14}$$

Eq. [13] and Eq. [14] show W-bar ($\bar{W}$) and Z-bar ($\bar{Z}$) statistics, respectively.

5. Results and Discussion

In this study, where we examine the linear impact of digitalization and globalization on income inequality, we start the econometric analysis with descriptive statistics.

Table 2: Descriptive Statistics

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis
lnGIN	3.662	3.676	4.151	3.285	0.197	0.076	2.644
lnGDP	8.822	8.921	10.247	6.648	0.685	-0.457	3.125
lnKOF	4.180	4.192	4.428	3.552	0.148	-0.897	4.194
DIG	-0.056	0.000	1.966	-2.091	0.941	-0.076	1.856
POL	-0.212	-0.131	1.116	-2.376	0.778	-0.342	2.228

In Table 2, mean and median values are highest for lnGDP and lnKOF, while the lowest are for DIG and POL. The highest standard deviation belongs to DIG (0.941), followed by POL (0.778), lnGDP (0.685), lnGIN (0.197), and lnKOF (0.148).

Table 3: The CSD Test Results

Test	lnGIN	lnGDP	lnKOF	DIG	POL
LM	4208.524 (0.000)	5733.306 (0.000)	6812.524 (0.000)	5906.452 (0.000)	1621.624 (0.000)
CD_{LM}	133.442 (0.000)	186.951 (0.000)	224.824 (0.000)	193.028 (0.000)	42.660 (0.000)
LM_{adj}	132.717 (0.000)	186.226 (0.000)	224.099 (0.000)	192.303 (0.000)	41.935 (0.000)
CD	2.947 (0.003)	65.178 (0.000)	71.442 (0.000)	47.424 (0.000)	-0.505 (0.613)

Note: Those in parentheses show probability values.

For all variables, Table 4 disproves the null hypothesis that there is no CSD between nations. In other words, there is a CSD in the panel. In this case, it can be argued that an economic, political or social shock in one of the countries may also affect other countries.

Table 4: The CIPS Unit Root Test Results

Variables	lnGIN	lnGDP	lnKOF	DIG	POL
CIPS (Level)	-1.410	-1.711	-2.137	-2.108	-2.231
CIPS (First Differences)	-2.075	-2.339	-4.810	-3.066	-4.102
Order of Integration	I (1)	I (1)	I (0)	I (0)	I (0)

Note: The critical values for the CIPS unit root test are -2.070, -2.15, and -2.32 at the 10%, 5%, and 1% significance levels, respectively.

Table 4 shows that the dependent variable, lnGIN, is integrated of I(1) while the independent variables, lnGDP is I(1), lnKOF is I(0), DIG is I(0), and POL is I(0). None of the variables pass the CIPS unit root test with an integration order greater than 1, demonstrating the applicability of the CS-ARDL.

Table 5: The CS-ARDL Estimation Results

Long-Run Results				
Dependent variable: lnGIN				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
lnGDP	-0.092	0.034	-2.750	0.006
lnKOF	-0.093	0.042	-2.220	0.026
DIG	-0.009	0.004	-2.180	0.029
POL	0.005	0.003	2.030	0.042
Short-Run Results				
lnGDP	-0.085	0.035	-2.420	0.015
lnKOF	-0.125	0.058	-2.150	0.032
DIG	-0.011	0.005	-2.180	0.029
POL	0.008	0.004	2.220	0.026
ECT (-1)	-1.393	0.060	-23.070	0.000

According to Table 5, the model's error correction term (ECT) is statistically negatively significant, with a 99% probability that the error correction mechanism of the estimated model works. The CS-ARDL results show that digitalization alleviates income inequality in the short and long run. Likewise, globalization and economic growth also negatively affect income inequality in the short and long run. However, political stability exaggerates income inequality. Hence, digitalization narrows the income gap in the EIEs. The positive results of digitalization on income equality mean that an increase in digitalization leads to a rise in productivity, enlarging economic activity, and participation in labour markets. In the final step of our empirical analysis, we show and evaluate the results of Dumitrescu and Hurlin (2012) panel causality test results.

Table 6: D-H Panel Causality Test Results

Null Hypothesis:	**W-Stat.**	**Zbar-Stat.**	**Prob.**	**Causality**
lnGDP ↛ lnGIN	5.012	5.226	0.000	lnGDP ↔ lnGIN
lnGIN ↛ lnGDP	3.801	2.864	0.004	
lnKOF ↛ lnGIN	5.781	6.724	0.000	lnKOF ↔ lnGIN
lnGIN ↛ lnKOF	4.578	4.379	0.000	
POL ↛ lnGIN	3.366	2.015	0.044	lnGIN ↔ POL
lnGIN ↛ POL	5.793	6.748	0.000	
DIG ↛ lnGIN	4.998	5.197	0.000	DIG ↔ lnGIN
lnGIN ↛ DIG	6.973	9.049	0.000	

The findings from Table 6 indicate a two-way causal relationship between economic growth, globalization, digitalization, and political stability concerning income inequality. The D-H results validate the existence of a relationship between variables obtained by the CS-ARDL.

6. Conclusions and Policy Implications

Digitalization has a significant impact on global economic structure and global society, including income inequality. This paper investigates the impact of digitalization on income inequality in 29 Emerging Industrial Economies (EIEs) from 2000-2020. According to the CS-ARDL results, globalization mitigates income inequality and show that a 1% increase in globalization causes a decrease in income equality by 0.093% in the long-run. Our negative result of globalization is in line with the study of Bechtel (2014), Han et al. (2023), and Ibrahim (2022) and contradicts the findings of Lee et al. (2020). This outcome can be attributed to the spillover effect of globalization, as the Heckscher-Ohlin theory says that globalization increases gains of abundant factors (Ibrahim, 2022). Also, globalization contributes to an increase in the labor force's productivity and closes the income gap between rich and poor (Lee et al., 2020).

Also, digitalization reduces income inequality in the EIEs. A 1 unit increase in digitalization (information and communication technology) is linked with a 0.9% decrease in income inequality in the long-run. It is consistent with previous studies of Yin and Choi (2023), Jing et al. (2019), Yao and Ma (2022), Patria and Erumban (2020), and Houngbonon and Liang (2021). As mentioned above, there are various mechanisms for decreasing income inequality. In particular, digitalization causes a decrease in transaction costs and increased productivity, resulting in increasing firms' profits and promoting new economic and employment opportunities (Yin and Choi, 2023). Furthermore, economic growth contributes to reducing income inequality; a 1% increase in economic growth reduces income inequality by 0.092% in the long-run. This finding is in line with Ha et al. (2019), Xu et al. (2021), Lee et al. (2022), and Gonese et al. (2022). However, it contradicts the findings of Rubin and Segal (2015), Munir and Sultan (2017), and Bucevska (2019). In his famous study, Kuznets (1955) pointed out an inverted U-shaped relationship between economic growth and income inequality, indicating that inequality increases in the early stage of economic growth but decreases after a threshold level. The negative effect of economic growth on inequality shows that the gap between skilled and unskilled people narrows in the long run, and economic growth stimulates social spending for poor people.

Finally, according to the results, political stability worsens income inequality. A 1 unit increase in political stability causes a rise in income inequality by 0.5% in the long-run. This result is in line with the study of Yin and Choi (2023) and Zehra et al. (2021). This is because most of the EIEs have a weak institutional capacity. Specifically, the political stability of these countries is far from the targeted level and comprehensive. Based on these findings, we suggest some policy implications. Firstly, governments in the EIEs should keep enacting laws to support the growth of digital technology. In order to fully benefit from digital technology, rules must be created to increase all workers' access to digital tools. Secondly, policymakers should extend digital financial opportunities. For example, the mobile infrastructure of countries should be strengthened, and policymakers should provide accessible digital tools for people. Also, governments of these countries should extend digital financial literacy among people. Thirdly, since economic growth positively affects income distribution, policymakers should promote sustainable and inclusive economic growth through direct taxes and tax exemptions for low-income individuals. Fourthly, the governments of these EIEs countries should implement well-developed institutional quality to realize access to digital technologies.

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