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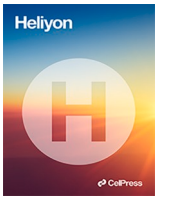

Research article

# Does the digital economy promote or inhibit income inequality?

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ABSTRACT

Digitalisation and technological developments are profoundly changing the socioeconomic structure of society and people's lifestyles, which may have a significant impact on the distribution of income among different groups of people. This study conducted a quantitative investigation into the impact of the digital economy on income inequality based on the skill bias theory. First, empirical model analysis showed that digital economy has a linear dampening effect on income inequality and that there is no non-linear relationship. Then, the study analyzed the mechanisms underlying this relationship, which revealed that mining and remittances suppress income inequality in the presence of digital economy, while government spending promotes income inequality. Finally, heterogeneity analysis indicated that the suppressive impact of digital economy on income inequality in capitalist countries is stronger than in ex-communist countries. These findings will not only help to achieve social equity, but also provide a strategic direction for economic development to make the dividends of the digital economy more inclusive.

## 1. Introduction

Income inequality is closely tied to social equity, economic development, and social stability. Income inequality refers to the uneven distribution of income among individuals or households in a given society, economy, or group [1]. This means that some individuals or households have relatively high incomes, while others have lower levels of income, resulting in significant income disparities throughout the society or economy. It has numerous negative effects on both individuals and the society as it can lead to social differentiation, unequal opportunities, and social unrest [2]. While most existing studies have focused on traditional factors that contribute to income inequality, the significance of the digital economy as a current driver of the global economy cannot be overlooked. The digital economy's impact on income inequality is multifaceted. It refers to the comprehensive digitisation and networking of economic activities driven by digital technology, with data as the core resource, and an economic form that creates value and promotes economic growth through the use of information technology [3]. The digital economy not only refers to the digital industry but also includes the digitisation of traditional industries, the Internet economy, e-commerce, big data, artificial intelligence, blockchain, and other applications of emerging technologies, which cover the comprehensive digitisation of all aspects from production, distribution, consumption to management. Characteristics of the digital economy include a high degree of informatisation, strong industrial integration, strong innovation drive, a high degree of globalisation, and more, which impact economic growth, employment, industrial restructuring, and consumption patterns [4]. Emerging industries and digital ways of working, such as internet businesses, freelancers, and online platforms, offer high salaries and flexibility and provide numerous income opportunities for skilled and highly

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skilled individuals [5]. Therefore, for some individuals, the digital economy creates new opportunities and well-paid employment that elevate their income levels.

Unemployed individuals respond to regional differences through expected individual wages, whereas the employed are more sensitive to employment opportunities [6]. Unfortunately, technological advancements can lead to a decline in traditional industries, resulting in unemployment and income pressures for some segments of the population [7]. In this manner, the digital economy also widens the income gap between certain groups of people. Hence, this paper argues that the digital economy is a critical factor that influences income inequality, however, its impact is complex and dependent on various factors. Therefore, it is essential to study the effect of the digital economy on income inequality within the context of emerging digital economies.

The objective of this study is to conduct a comprehensive investigation of the relationship between the digital economy and income inequality, focusing on business activities, government interventions, and financial transactions, while taking into account differences across countries. Through an in-depth analysis, this study seeks to understand how income distribution is affected in the context of mining activities. In addition, this study examines how government spending on education, skills training, and entrepreneurship affects income inequality in the context of the digital economy, thus highlighting the importance of balanced government policies. In addition, this study provides insights into how digital financial flows, particularly remittances, affect income distribution but which may also widen income gaps due to unequal access and utilisation. By considering these mechanisms and their variations across countries, this study aims to provide valuable insights for policymakers and stakeholders to address the challenges of income inequality in the digital age, ultimately contributing to more inclusive and equitable economic development strategies globally. To achieve this goal, both static and dynamic estimation methods were employed to provide an overview of the impact of the digital economy on income inequality. To achieve this goal, both static and dynamic estimation methods were employed to provide an in-depth analysis of balanced panel data for the EU28 from 2015 to 2021, and robustness tests were conducted to verify the reliability of the results. Finally, the full sample was divided into multiple subsamples heterogeneity analysis, and the results obtained provided important insights.

First, the growth of the digital economy can affect income inequality through business activities. The adoption of digital technologies in mining activities, for example, can improve productivity, resource utilisation, and safety. In the mining industry, sensors and data analytics can enable more accurate ore exploration and resource management, which reduce waste and increases efficiency [8]. This, in turn, leads to increases in jobs, incomes, and income equality. However, the growth of the digital economy can also give rise to a digital divide, which creates a gap between those with access to digital skills and resources and those without. In the case of mining activities, if certain mining areas fail to keep up with digitisation, they may miss out on the opportunities offered by the digital economy that exacerbates income inequality.

Second, the growth of the digital economy can influence income inequality through government expenditure. As the digital economy expands, governments can reduce income inequality by increasing investment in education, skills training, and entrepreneurship. This approach promotes digital access and inclusion while providing more opportunities and resources for low-income groups [9]. However, if the government overly-prioritises the digital economy at the expense of other crucial areas, it may exacerbate income disparity. In such a scenario, the benefits of the digital economy may be primarily enjoyed by only a few affluent groups, leaving the marginalised and disadvantaged groups unable to access the opportunities and advantages offered by the digital economy; thus, this widens income inequality.

Third, the digital economy can impact income inequality through its influence on remittances. With the growth of the digital economy, sending money abroad through digital channels becomes more cost-effective, transparent, and secure, which promotes financial inclusion [10]. This offers a convenient and affordable way for low-income groups to send remittances, thereby increasing their disposable income and reducing income inequality [11]. However, it is worth noting that digital channels may primarily benefit those with higher incomes and financial resources. Higher-income groups are more likely to use digital channels for larger remittances and investments, which enhances their wealth and income. Meanwhile, disadvantaged groups may face challenges like information asymmetry and lack of skills, which limit their opportunities in the digital economy that lead to income inequality.

Overall, this study offers novel insights into the correlation between the digital economy and income inequality and aimed to address a significant research gap within EU countries. Its contribution is multifaceted. Firstly, the study sheds light on the intricate relationship between the digital economy and income inequality within EU economies and provides valuable insights into this relatively unexplored area of research. By delving into this relationship, the study not only enhances our understanding of income distribution dynamics but also contributes to broader discussions on economic development and social equity. Secondly, the study breaks new ground by considering the role of moderating variables such as mining activities, government expenditures, and remittances. By incorporating these factors into the analysis, the study deepens our understanding of the mechanisms through which the digital economy influences income inequality. This nuanced approach allows for a more comprehensive assessment of the multifaceted nature of income inequality within the context of the digital economy. Lastly, the study adopts a multilevel research design to analyse heterogeneity across EU countries by considering variations in institutional frameworks and policy environments. By examining how institutional differences shape the relationship between the digital economy and income inequality, the study provides valuable insights into the contextual factors that influence this relationship. This nuanced understanding of cross-country variation enhances the applicability and relevance of the study's findings for policymakers and researchers alike.

The paper's structure can be summarised as follows. The first section serves as an introduction, which provides a brief overview of the study's purpose and significance. In the second section, the relevant literature is reviewed, which incorporates previous research and theoretical frameworks. The third section describes the data sources and methodologies employed, while the fourth section presents a detailed analysis of the empirical results and offers a comprehensive discussion of the findings. Lastly, the fifth section summarises the key findings and proposes policy recommendations.

## 2. Literature review

### 2.1. Theoretical literature review

The skill bias theory, proposed by Berman [12] suggests that technological advancements tend to favour highly skilled labour over low-skilled labour. This theory highlights that technological changes are not uniform but rather tend to increase the demand for skilled workers, potentially exacerbating income inequality. Card and DiNardo [13] expanded on this theory, discussing the complexities and puzzles associated with skill bias and wage-income inequality. Violante [14] further deepened the understanding of the skill bias theory by emphasising on the central role of technological change in the income distribution debate. As technological advancements often lead to an increased demand for skilled labour, they become closely linked to wage inequality.

In the context of the digital economy, as noted by Litvinenko [15], technological change is the driving force. The growth of the digital economy typically requires highly skilled workers to adapt to and utilise new technologies, leading to increased productivity and earnings for this segment of the workforce. Conversely, low-skilled workers may face challenges such as job displacement or lower wage levels due to technological change, which contribute to income inequality. Therefore, technological advancements and disparities in skill levels emerge as key factors influencing income distribution within the digital economy [16].

In short, the skill bias theory underscores the role of technological change in shaping income inequality, particularly within the context of the digital economy. It highlights the differential impact of technology on skilled and unskilled workers and emphasises the need for policies and interventions to address skill disparities and mitigate income inequality in the digital age.

### 2.2. Literature review of the impact of the digital economy

The rapid growth of the digital economy has increased the demand for highly skilled labour, making it easier for those with advanced skills such as digital skills and data analytics to find well-paying employment opportunities in the digital economy. In contrast, those with relatively low skills may become unemployed or face salary pressures in the process [17]. Second, the rise of the platform economy has also exacerbated income inequality, leading to the possibility that a small number of platform owners and highly skilled platform practitioners may reap large profits, while other small and medium-sized enterprises (SMEs) may face greater competitive pressures [18]. In addition, data capitalism in the digital economy views data as a form of capital, with ownership and control of data being key to economic competition. Hence, firms or individuals with more data and better data analytics are more likely to create and capture value, which would also lead to income inequality. Finally, changes in the labour market are also an important factor, as the digital economy has brought about the rise of teleworking, freelancing, and online labour markets, which provide opportunities for people globally to participate in the economy but may also lead to some regions or occupations facing a reduction in employment opportunities, thus exacerbating income disparities between geographies and occupations.

Currently, relevant research offers different perspectives on the impact of the digital economy on growth. Al-Roubaier et al. [19] argued that a new economy powered by digital technologies can drive output diversification and promote economic growth. The enhanced communication capabilities of digital networks enable people, regions, and countries to collaborate and share information more easily, thereby promoting growth and sustainable development. León et al. [20] found that advances in information and communication technologies (ICT) provide new opportunities for firms to expand their horizons, explore new markets, and diversify their businesses. Diversified firms also exhibit higher levels of ICT use, which positively impacts the degree of international diversification and business relationships. Gan et al. [21] investigation showed that ICT plays a key role in helping firms in rural areas achieve global connectivity and enhance marketing and promotion. However, Solomon and van Klyton [22] study pointed out differences in the impact of ICT use on economic growth among individuals, businesses, and the government, with only individual use having a positive impact while others did not. Furthermore, Owolabi et al. [23] study found that landline and ICT imports significantly reduced economic diversification, while internet and mobile technologies did not have a significant impact economic diversification, which is in line with the study of Solomon and van Klyton [22]. Taken together, the digital economy may have a facilitating impact on economic growth, but it may also have a dampening impact that requires further in-depth research.

### 2.3. Literature review affecting income inequality

The literature is rife with extensive research that have studied the factors affecting income inequality in cities. The identified factors include social policy [24], economic development [25], international trade [26], population [16], economic globalisation [27], technological change [28], monetary and tax policies [29], corruption [30], employment [31], demographic behaviour [32], economic zones [33], and risk-based capital rules for international lending [34]. Despite the wealth of research on the digital economy, however, research on its impact on income inequality is relatively limited. Current research mainly focuses on Chinese urban and provincial data. Peng and Dan [8] and Wu et al. [35], for instance, found a U-shaped relationship between the development of the digital economy and income disparity using Chinese urban and provincial data. Ma and Zhang [36], by analysing data on China's ethnic minorities, concluded that the digital economy helps to raise income levels and narrow the income gap. Although many scholars have analyzed the impact of the digital economy on Chinese provinces and cities in depth, this study chose to break through this limitation by using data from EU countries to explore the impact of the digital economy on income inequality in a new way. In this study, the focus was not only on data from EU countries, but also considered, for the first time, the moderating role of three key factors which are mining activities, government expenditures, and remittances of the digital economy on income inequality. This innovative research design not only expands the scope of the study but also provides new perspectives for a deeper understanding of the

mechanisms through which the digital economy affects income inequality.

### 2.4. Literature review of nonlinear effects

Previous studies have identified financial deepening [37], financial development [38], climate change and precipitation anomalies [39], and human capital development [40] as factors that have nonlinear effects. While there has been much research on the nonlinear impact of multiple factors on income inequality, research on the potential nonlinear relationship between the digital economy and income inequality is still quite limited. For example, Peng and Dan [8] and Wu et al. [35] found a U-shaped relationship between digital economy development and income disparity using urban and provincial data in China, however, these findings are only applicable to China and are not generalisable. Therefore, to address this gap in the literature, this study analyses the possible non-linear effects of the digital economy on income inequality under different samples. Through this unique perspective, a more comprehensive and deeper understanding of the relationship between the digital economy and income inequality is expected, which will provide valuable references for future research and policy formulation.

### 2.5. Hypothesis development

The digital economy influences economic growth [41]. In turn, economic growth affects income inequality [25]. Therefore, this study predicted a significant effect of digital economy on income inequality, which leads to the following hypotheses:

**H1a**. digital economy affects income inequality.

**H1b**. digital economy does not affect income inequality.

Income inequality is influenced by various business behaviours, many of which are closely tied to the digital economy. When analysing digital economy from the perspective of business behaviour, it becomes evident that technological innovations, such as blockchain, the Internet of Things, and artificial intelligence, play a significant role. These technologies have the potential to transform various industries and affect the way it is operated and managed. For instance, in the mining industry, blockchain technology could enhance supply chain transparency and security, the Internet of Things could enable intelligent monitoring and management of mining operations and equipment, and artificial intelligence could optimise mineral resource exploration and extraction efficiency. Litvinenko [15] emphasised the impact of digital economy on the mining industry, while Chavez [42] demonstrated that mining, in turn, affects income inequality. Thus, by examining the business activities within the mining sector, it is possible to gain insights into how digital economy affects income inequality. Therefore, the following hypotheses were proposed:

**H2a**. digital economy promoting income inequality through mining development.

**H2b**. digital economy inhibiting income inequality through mining development.

The rise of the digital economy is often accompanied by the emergence of new industries and economic growth, leading to the creation of numerous jobs and entrepreneurial opportunities. This, in turn, generates increased tax revenue for the government, which provides sufficient funding for government expenditure [43]. However, the advancement of the digital economy has also had some effects on government expenditure and may contribute to the widening of income inequality. The technological gap that leads to social differentiation influences the decisions that governments make regarding the allocation of resources and social benefits, which potentially widens income gaps. Additionally, the rapid expansion of the digital economy has rendered certain traditional industries obsolete and resulted in the loss of related jobs, which further exacerbates income inequality. Nevertheless, there is an opportunity for governments to utilise the additional financial resources generated by the digital economy to implement social welfare policies and provide essential public services like education, healthcare, and social security. By doing so, they can work towards reducing income disparities. Moreover, technological innovations and digital services within the digital economy can enhance economic efficiency and promote fairness in resource allocation. These advancements can create opportunities and a more level playing field for a broader segment of the population that contribute to the goal of income equalisation. Therefore, the following hypotheses were proposed:

**H3a**. the digital economy promoting income inequality through government expenditure.

**H3b**. the digital economy inhibiting income inequality through government expenditure.

The digital economy affects remittances [44], which in turn influences income inequality [45,46]. It has given rise to electronic payment and remittance services on a global scale, which requires appropriate digital devices and Internet connectivity. Consequently, those without access to these digital resources may be excluded from the convenience of digital remittances, leading to an increase in income inequality. On the other hand, the digital economy makes it easier and more affordable to send remittances across borders, which means that low-income and marginalised groups can receive funds more easily. This reduces barriers to financial services and may alleviate income inequality. Therefore, the following hypotheses were proposed:

**H4a**. the digital economy promoting income inequality through remittances.

**H4b**. the digital economy inhibiting income inequality through remittances.

This study predicted the impact of digital economy on income inequality to be not only significant but non-linear. In the initial phase of the digital economy, emerging technologies and innovations create new business opportunities and jobs, which provide

opportunities for economic growth and social mobility for more people, thus minimising income disparities [47]. However, as the digital economy matures and become more centralised, several large corporations monopolise the market, leading to more extreme wealth concentration. The monopolistic position of these firms and unequal market power can lead to increased income inequality and limited economic opportunities for the marginalised and underprivileged groups [48]. Therefore, the following hypotheses were proposed:

**H5a**. There is a nonlinear relationship between digital economy and income inequality.

**H5b**. There is no nonlinear relationship between digital economy and income inequality.

To facilitate further understanding of the content and ideas in this paper, a comprehensive analytical framework has been presented in Fig. 1. The figure illustrates the relationship between the digital economy and income inequality, including the interacting mechanisms and other key concepts in this study.

## 3. Research methodology and data

### 3.1. Dependent variable

Income Inequality (*Inequality*): *Inequality* is the dependent variable of this study. It was represented in this study by inequality in the distribution of income, which is the ratio of the total income received by the top 20 % of the population (top quintile) to the total income received by the bottom 20 % (bottom quintile). The data for *Inequality* was derived from the European Statistical Office.

### 3.2. Independent variables

Digital Economy (*Digital*): *Digital economy* is the explanatory variable of interest in this study. To adequately evaluate digital economy levels in the EU28, the Digital Economy and Society Index of EU countries was chosen as the measurement, the data of which is available from the European Commission. The Digital Economy and Society Index (DESI) for EU countries is a composite indicator that assesses the level of development of European countries in the digital economy and society. The index consists of five main dimensions covering digital connectivity, digital skills of human capital, use of Internet services, digitisation levels of businesses, and digitisation of public services. The connectivity dimension measures the quality and penetration of the Internet and broadband infrastructure and people's use of digital technologies. The digital skills dimension assesses people's digital literacy and basic ICT skills. The usage dimension looks at people's activities on the Internet, such as online shopping and social media use. The digital business dimension examines how well businesses are doing digitally, including e-commerce adoption and the use of digital technologies in business. Finally, the digitalisation of public services dimension assesses the digital services provided by governments and public institutions, including online government services and e-health services. By combining these dimensions and related indicators, DESI provides each EU member state with a comprehensive assessment of its digital development, which can help promote the sustainable growth of the digital economy and society.

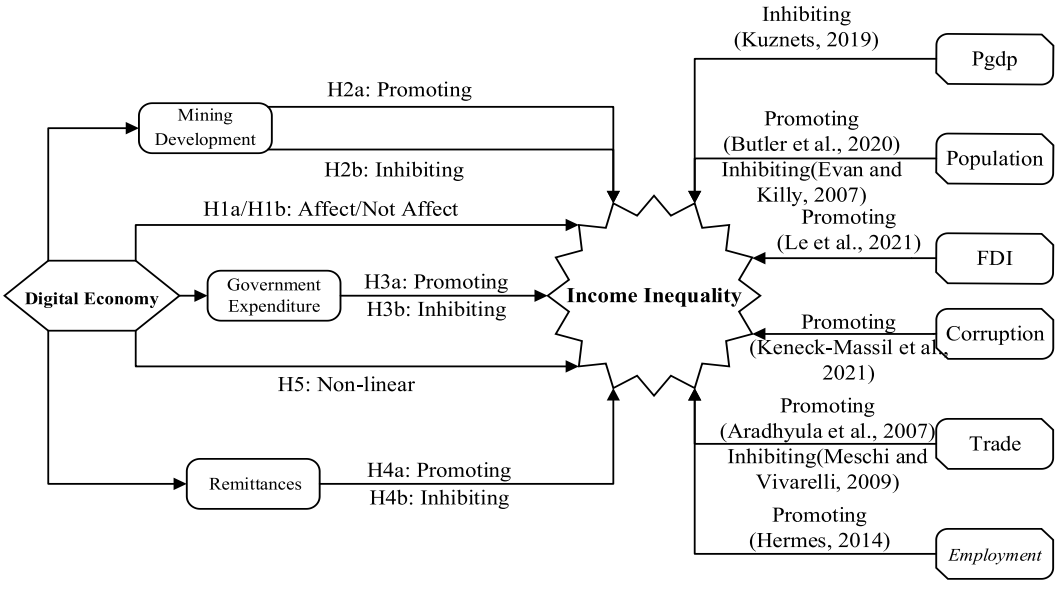


**Fig. 1.** Comprehensive analytical framework.

### 3.3. Control variables

Per Gross Domestic Product (*Pgdp*): Economic growth is a critical influencing factor of income inequality in a country [25,49]. Therefore, this study measured economic growth in the sample of EU28 countries using GDP per capita, with the expected result that GDP per capita reduces income inequality.

Country Population Size (*Population*): The size and dynamics of a country's population affect income inequality [16]. When a country's population grows, competition in the job market increases, which may lead to lower wages for low-skilled jobs; this increases income inequality [50]. Simultaneously, population growth drives the demand for education and training resources. Governments and societies would invest in the development of education systems, thereby increasing people's employability and income levels, which can help reduce income inequality [51]. Therefore, this study used the total population of the sample EU28 countries to measure their population size, with the expected result that population size may increase or decrease income inequality.

Foreign Direct Investment (*FDI*): FDI may lead to the emergence of monopolies within industries, especially when a few large multinational companies control the market [52]. These transnational corporations may be able to manipulate prices and market conditions, thereby limiting competition and reducing opportunities for other small local firms. In doing so, these monopolies may lead to increased income inequality [53]. This study used the annual net FDI inflows as an indicator of the level of national FDI growth in the EU28. The direction of the relationship between FDI and income inequality was expected to be positive.

International Trade (*Trade*): International trade is one of the factors that influence income inequality [26]. The growth of international trade can create more market opportunities that contribute to business growth and job creation [54]. When businesses expand their operations, they create more jobs and provide additional sources of income, thereby reducing income inequality for a segment of the population. International trade can also intensify competition in some industries, particularly low-skilled labour-intensive ones. This may lead to lower wages, especially for workers who are less competitive in international markets, which may increase income inequality [55]. Therefore, this study used total trade to measure the size of trade in the sample EU28 countries, with the expected outcome being that trade may increase or decrease income inequality.

Country Corruption (*Corruption*): Corruption can lead to unfair competition in the market economy. It can also lead to market distortions that concentrate on wealth and opportunities in the hands of a few classes, thereby increasing income inequality [30]. Therefore, this study selected the National Corruption Index as a measure of corruption and expected it to increase income inequality.

Country Employment (*Employment*): The increase in employment affects income inequality [31]. When employment rises, there are fewer unemployed people and labour supply becomes relatively stable, which can lead to wage increases in the labour market [56]. For low-income people in particular, access to jobs and higher wages can significantly improve their income level and reduce income inequality [57]. Therefore, in this study, the national employment rate was chosen to measure level of employment, which was expected to reduce income inequality.

### 3.4. Data description

This study utilised panel data on the EU28 countries covering the period from 2015 to 2021. Data was collected from reputable sources such as the European Statistical Office, the World Bank's World Development Indicators database, and the Transparency International database. Descriptive statistics for the entire dataset can be found in Table 1. To ensure the validity of the analysis, the existence of multicollinearity was tested in this study, wherein Variance Inflation Factor (VIF) values were calculated for all variables. The results indicated that all VIF values were less than 5.0, which alleviated concerns about estimation bias that result from multicollinearity. The detailed results of these tests are available in Appendix A1.

### 3.5. Empirical methodology

This study used a fixed effects model for the analysis. To test hypothesis H5a and H5b, the squared term of *Digital* was added to the estimated model. In addition, all variables except *Inequality* and *FDI* were taken to be logarithmic. Specifically, the core explanatory variable (*Digital*) and the control variables (*Pgdp, Trade, Corruption, Population, and Employment*) were computed as logarithms to minimise heteroskedasticity. Finally, a panel data model was developed, as presented in Equation (1) and Equation (2). If the U-shaped effect proposed by H5a exists, then α1 and α2 would be negative and positive, respectively, and statistically significant. To ensure the

**Table 1**
Descriptive statistics of full sample.

| Category | Variable Name | Measurement | Mean | Standard Deviation | Min | Max | Expected Sign |
|---|---|---|---|---|---|---|---|
| Dependent variable | *Inequality* | Index | 4.83398 | 1.222843 | 3.03 | 8.32 | |
| Independent variable | *Digital* | Index | 51.44235 | 9.892566 | 32 | 72.3 | |
| Control variables | *Pgdp* | US$ | 259109.3 | 839,570 | 2870 | 5,690,600 | – |
| | *Population* | People | 1.61e+07 | 2.16e+07 | 445,053 | 8.32e+07 | +/− |
| | *FDI* | US$ Billion | 17.2901 | 57.84633 | −344.38 | 322.55 | – |
| | *Trade* | US$ Million | 204431.9 | 301948.6 | 2607 | 1,636,742 | +/− |
| | *Corruption* | Index | 64.80102 | 14.45368 | 41 | 91 | + |
| | *Employment* | Index | 57.85078 | 4.734575 | 44.198 | 65.159 | – |

stability of the non-linear relationship results, a *U* test was also included. If the *U* test fails, H5b would be supported. The squared term of *Digital* would then be eliminated from the model, and the new model would be set up as Equation (3) and Equation (4) to be re-estimated.

$$Inequality_{it} = \alpha_0+\alpha_1 Digital_{it}+\alpha_2 Digital_{it}^2+\mu_i+\nu_t+\xi_{it} \quad (1)$$

$$Inequality_{it} = \alpha_0+\alpha_1 Digital_{it}+\alpha_2 Digital_{it}^2+\beta Z_{it}+\mu_i+\nu_t+\xi_{it} \quad (2)$$

$$Inequality_{it} = \alpha_0+\alpha_1 Digital_{it}+\mu_i+\nu_t+\xi_{it} \quad (3)$$

$$Inequality_{it} = \alpha_0+\alpha_1 Digital_{it}+\beta Z_{it}+\mu_i+\nu_t+\xi_{it} \quad (4)$$

In Equation (1), $\mu_i$ and $\nu_t$ are the effects of country and year, respectively. *Z* denotes all control variables affecting income inequality, α1, α2 and β denote the estimated coefficients and ξ denotes the errors. To assess the reliability of the benchmark estimation, different robustness checks were used. As mentioned earlier, the inequality of the Eurostat income distribution was used as a measure of income inequality. For robustness testing, this measure was replaced with the Gini coefficient and the benchmark test was re-estimated. This proxy for income inequality has been used by other scholars, such as Mendonça and Esteves [58] and Rashad et al. [59].

Because there could be underlying deficiencies in the study design, the observed impact of digital economy on income inequality based on the benchmark regression may be coincidental. To address this concern, a placebo test was conducted following the methodology described in Ding et al. [60], Cong et al. [61] and Cong et al. [62]. In this test, all data was removed from the sample and then randomly reallocated before re-estimating the baseline test. If the observed influence of digital economy on income inequality in the baseline model is genuine and not coincidental, the outcomes of the placebo test should not exhibit a similar causal relationship.

## 4. Results and discussion

### 4.1. Baseline regression results

Equation (1) was initially estimated using a panel fixed effects model, and the results are presented in the first column of Table 2.

**Table 2**
Results of baseline regression and robustness tests.

| | Baseline regression | | | Endogenous resolution | Robustness checks | | | |
|---|---|---|---|---|---|---|---|---|
| | Fixed effect | | | Two-stage least squares | Variable replacement | | Placebo effect | |
| | I | II | III | IV | V | VI | VII | VIII |
| $Digital_{it}$ | −3.2071*** | −3.0996*** | −4.8929*** | −3.0962*** | −0.2908*** | −2.6792*** | 5.1535 | 7.5395 |
| | (-9.0765) | (-8.0350) | (-10.4930) | (-4.3129) | (-6.3823) | (-4.9568) | (5.3447) | (7.6254) |
| $Digital_{it}^2$ | 2.8463*** | | | | | | | |
| | (4.8916) | | | | | | | |
| *Ln(PGDPit)* | | | −0.2696*** | −0.0596*** | | −0.0311*** | | −0.2304*** |
| | | | (-5.0801) | (-6.9879) | | (-4.8618) | | (-4.3974) |
| *Ln(Populationit)* | | | 0.6292*** | 0.1575*** | | −0.2278*** | | 0.7961*** |
| | | | (4.3208) | (4.2679) | | (-3.9559) | | (5.6819) |
| *Ln(Tradeit)* | | | −0.5171*** | −0.0375*** | | −0.0293*** | | −0.6646*** |
| | | | (-3.9101) | (-4.5652) | | (-2.9231) | | (-5.1558) |
| *FDIit* | | | −0.0002 | −0.0042 | | −0.0222 | | −0.0002 |
| | | | (-0.1644) | (-1.1446) | | (-0.2818) | | (-0.1576) |
| *Ln(Corruptionit)* | | | 1.3516*** | 0.0173*** | | 0.0040 | | 1.4913*** |
| | | | (4.4911) | (3.0730) | | (1.1687) | | (3.3375) |
| *Ln(Employmentit)* | | | 1.8634*** | 0.0232*** | | 0.0398*** | | 1.6473*** |
| | | | (4.0566) | (3.9976) | | (3.4550) | | (4.8192) |
| Constant | 3.4938*** | 3.9891*** | 3.6878*** | 3.1538*** | 4.5213*** | 5.2250*** | 3.1095*** | 4.7117 |
| | (11.0149) | (11.2163) | (13.2768) | (11.9735) | (10.2729) | (11.2438) | (5.0358) | (5.1030) |
| R-squared | 0.446 | 0.472 | 0.487 | | 0.434 | 0.469 | 0.411 | 0.437 |
| DWH | | | | 41.27 (p = 0.000) | | | | |
| Shea's Partial $R^2$ | | | | 0.685 (*Digital*) | | | | |
| ***U* Test** | | | | | | | | |
| Extreme point | | 4.21 | | | | | | |
| | | Lower | Upper | | | | | |
| Interval | | 3.47 | 4.28 | | | | | |
| Slope | | −7.3 | 0.67 | | | | | |
| t-value | | −7.49 | 0.49 | | | | | |
| P > t | | 0.00 | 0.31 | | | | | |
| t-value | | 0.49 | | | | | | |
| P | | 0.31 | | | | | | |

Note: t-statistics in parentheses, ***, **, and * indicate statistical significance at the 1 %, 5 %, and 10 % levels, respectively.
Test: $H_1$: U-shape vs. $H_0$: Monotone or Inverse U-shape.

The coefficients of both *Digital* and its squared term were found to be statistically significant at the 1 % level, with a negative and positive sign, respectively. This provided evidence that hypothesis H1a holds and suggested the presence of a U-shaped effect of digital economy on income inequality. To validate this inference, a U-shaped test was conducted on the sample of all countries (see results in Table 2). The test revealed that the U-shaped relationship between digital economy and income inequality did not exist. Thus, hypothesis H5a was rejected. According to the existing literature in comparison, Peng and Dan [8] and Wu et al. [35] found a U-shaped relationship between digital economy development and income disparity using Chinese city data and Chinese provincial data, respectively. This relationship, however, was not observed in this paper's study using EU28 data and may involve multifaceted differences at the city level in EU countries and China. In EU countries, relatively balanced levels of development, well-developed social welfare systems, generally high levels of education, and more stable labour markets may have slowed down the impact of the digital economy on income disparity, which created a less pronounced U-shaped relationship. In contrast, the existence of large imbalances among Chinese cities, the diversity of population groups, and government policies promoting urbanisation and digitisation were potential factors that may have led to the U-shaped relationship between the development of the digital economy and income disparity. Thus, economic, social, and policy differences at the national and city levels may be the main reason for the differences in the study results.

Since there was no evidence of a non-linear relationship between digital economy and income inequality, the relationship using Equation (3) and Equation (4) was re-estimated. The results are reported in columns II and III of Table 2, where the control variables are excluded in column II and included in column III. Across all models, the coefficient of *Digital* remained negative and statistically significant at the 1 % level. This indicates that digital economy has a dampening effect on income inequality, and the relationship appears to be linear. This is consistent with the results found by Xu [63] whose panel data confirmed that the digital economy has a dampening effect on income inequality. As a result, hypothesis H1 was supported. By analysing the control variables in the main model (column III), the coefficients of *Population, Corruption,* and *Employment* were found to be positive and statistically significant, suggesting that a larger population size, higher corruption levels, and increased employment are associated with higher income inequality. This is in line with Deaton and Paxson [64] who found that an increase in population size exacerbates income inequality, while this paper supports the findings of Gupta et al. [65] and others who found that high and increasing corruption exacerbates income inequality. The coefficient of *FDI* was also positive but lacked statistical significance, indicating that FDI may promote income inequality, but it is not a significant factor in doing so. This is inconsistent with the findings of Yuldashev et al. [66], who found that FDI significantly contributes to income inequality in 10 districts across Asian regions based on a panel dataset of empirical studies covering 10 districts in each Asian region for the period 1990 to 2020. This difference may be due to the positive but insignificant coefficient of FDI in the EU28 study, which may reflect the relatively developed economic system of the EU, in which foreign investment focuses more on technological innovation and industrial upgrading and does not contribute statistically significantly to income inequality. On the contrary, the Asian regional study found that FDI contributed significantly to income inequality. Hence, this may reflect the more complex economic structure of certain countries or regions, where FDI is more concentrated in resource-based or labour-intensive industries and lead to resource inequality and limited employment opportunities, thus increasing the likelihood of income inequality. Conversely, the coefficients of *Pgdp* and *Trade* were negative and statistically significant, implying that economic growth and trade development tend to reduce income inequality. Rubin and Segal [67] found that economic growth promotes income inequality using US time series data from 1953 to 2008. The difference in results may be because this paper selected European countries within a more concentrated region, whereas the U.S. time-series data cover a broader period and may include multiple economic periods experienced in the United States. Such period and regional differences may reflect different economic contexts, policy environments, and social structures, leading to different insights into the impact of economic growth and trade on income inequality.

It is worth noting that all control variables, except *Employment* aligned with their expected sign. This can be attributed to the fact that different occupations require varying levels of skills and education. In EU countries, high-skilled and highly educated occupations in fields like science, technology, engineering, and mathematics often command higher salaries, while lower-skilled and less educated occupations, such as in services and agriculture, are typically less well-paid. Consequently, despite an increase in employment, income inequality may widen due to significant disparities in pay levels, which contribute to overall income inequality.

### 4.2. Endogenous resolution

The results of the baseline regressions may be endogenous: income inequality may also have a reverse effect on national digital economy development. In this study, the interaction term between the number of landline telephones per year (per 100 people) and the number of Internet users in the previous year in the EU28 from 2015 to 2021 were used as an instrumental variable to resolve potential endogeneity issues. This approach was adopted because, according to Chen et al. [68], an increase in the number of fixed line telephone calls could foster the development of the digital economy by providing access to a wider range of communication infrastructures and connectivity opportunities, as well as facilitate digital transformation and the diffusion of Internet services. Conversely, a decline in the number of fixed line telephones may limit the growth of the digital economy and reduce the penetration of communication and Internet services. Therefore, the instrumental variable met the relevant requirements; furthermore, there was no direct relationship between changes in the number of fixed-line telephones and income inequality, which was also consistent with the assumptions about the nature of the instrumental variable. Therefore, it was tested using the two-stage least squares method, the results of which are shown in column IV of Table 2. Firstly, the explanatory variables in the model of this study were tested for endogeneity and the results showed that the DWH test statistic was 41.27, $P = 0.000 < 0.01$, i.e., it reached the significance level of 1 percent, therefore, the original hypothesis that all the explanatory variables were exogenous was to be rejected. Instead, it was argued that there was a

problem of endogeneity of the explanatory variables in the model of this study. The validity of the instrumental variables was further tested, and the results showed that the Shea part $R^2$ of the instrumental variables was around 0.1. Therefore, it was considered that there was no weak instrumental variable problem. Based on the results of the two-stage least squares test, the results showed that digital economy development significantly suppressed income inequality, proving that the benchmark results were robust.

### 4.3. Robustness test results

To check the robustness of the baseline regression, relevant robustness tests were conducted. The results of these tests are presented in columns V to VIII of Table 2. In Columns V and VI, the explanatory variable *Inequality* was replaced with the Gini coefficient. The results indicated that digital economy reduced income inequality, which verified the validity of the benchmark results. Next, the results of the placebo tests (columns VII and VIII) showed that the coefficients obtained were mostly statistically insignificant and differed significantly from the baseline estimates, confirming that the results of the baseline model were not placebo effects. Overall, the robustness tests supported the validity of the baseline regression results.

### 4.4. Further analysis

#### 4.4.1. Mechanism analysis

Building on existing research evidence, this study also tested the mechanisms linking digital economy to income inequality. It was suggested earlier that the digital economy may affect income inequality through three main channels: mining activities, government spending, and remittances. This section reports the empirical testing of these propositions. First, as shown in Equation (5), the interaction term between digital economy and mining, (Digital)*Ln (Mining), was added to Equation (4). Similarly, the interaction terms (Digital)*Ln (Government) and (Digital)*Ln (Remittances) were added to Equation (4) to obtain Equation (6) and Equation (7), respectively. All the variables in Equations (5)–(7) were the same as those in Equation (4).

$$Inequality_{it} = \alpha_0+\alpha_1 Digital_{it}+\alpha_1((Digital_{it})*\mathrm{Ln}(Mining_{it}))+\beta Z_{it}+\mu_i+\nu_t+\xi_{it} \quad (5)$$

$$Inequality_{it} = \alpha_0+\alpha_1 Digital_{it}+\alpha_1((Digital_{it})*\mathrm{Ln}(Government_{it}))+\beta Z_{it}+\mu_i+\nu_t+\xi_{it} \quad (6)$$

$$Inequality_{it} = \alpha_0+\alpha_1 Digital_{it}+\alpha_1((Digital_{it})*\mathrm{Ln}(Remittances_{it}))+\beta Z_{it}+\mu_i+\nu_t+\xi_{it} \quad (7)$$

Table 3 presents the results of the estimated mechanisms underlying the relationship between digital economy and income

**Table 3**
Mechanism tests.

| | Mining Activity | | Government expenditure | | Remittances | |
|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI |
| *Digitalit* | | −2.2966* | | −2.4774** | | −2.0265*** |
| | | (-3.9657) | | (-4.1497) | | (-4.6806) |
| *Ln(PGDPit)* | −0.2394*** | −0.2076*** | −0.1627*** | −0.1854*** | −0.3001*** | −0.2447*** |
| | (-4.5003) | (-3.8402) | (-3.1755) | (-3.5949) | (-5.5828) | (-4.5894) |
| *Ln(Populationit)* | 0.8543*** | 0.8679*** | 0.9719*** | 0.8827*** | 0.5695*** | 0.7470*** |
| | (5.2184) | (5.1269) | (7.1352) | (6.0651) | (3.9105) | (5.2141) |
| *Ln(Tradeit)* | −0.6026*** | −0.7061*** | −0.7712*** | −0.6825*** | −0.5905*** | −0.7035*** |
| | (-4.5193) | (-5.2422) | (-6.2608) | (-5.2862) | (-4.4156) | (-5.2100) |
| *FDIit* | −0.0002 | −0.0004 | −0.0011 | −0.0007 | −0.0002 | −0.0003 |
| | (-0.1592) | (-0.3008) | (-0.9514) | (-0.5854) | (-0.1362) | (-0.2626) |
| *Ln(Corruptionit)* | 1.5618** | 0.9026 | 0.3457 | 0.6489 | 1.7964*** | 0.9232 |
| | (2.5065) | (1.4462) | (0.7292) | (1.0502) | (2.8186) | (1.4414) |
| *Ln(Employmentit)* | 0.6529*** | 0.1380*** | 0.4216 | 0.1576 | 0.6072*** | 0.4761*** |
| | (3.9071) | (3.8139) | (0.3783) | (0.1347) | (2.0734) | (2.9822) |
| *Ln(Miningit)* | −0.0919*** | −0.1237*** | | | | |
| | (-3.8233) | (-3.2796) | | | | |
| *Digitalit*Ln(Miningit)* | | −0.4411** | | | | |
| | | (-2.3365) | | | | |
| *Ln(Governmentit)* | | | −2.2461*** | −2.7626*** | | |
| | | | (-4.8443) | (-6.4016) | | |
| *Digitalit*Ln(Governmentit)* | | | | 2.4896** | | |
| | | | | (5.0963) | | |
| *Ln(Remittancesit)* | | | | | 0.2312** | 0.8072* |
| | | | | | (2.4915) | (1.4185) |
| *Digitalit*Ln(Remittancesit)* | | | | | | −0.5862* |
| | | | | | | (-1.7135) |
| Constant | 3.1888*** | 3.9741*** | 8.2178* | 8.9030*** | 3.6600*** | 9.5782* |
| | (9.8640) | (11.6746) | (10.7269) | (12.7197) | (9.2672) | (10.9352) |
| R-squared | 0.471 | 0.478 | 0.481 | 0.493 | 0.466 | 0.479 |

Note: t-statistics in parentheses, ***, **, and * indicate statistical significance at the 1 %, 5 %, and 10 % levels, respectively.

inequality. Columns I and II focused on the mediating role of mining activity in this relationship. In column II, the interaction term (Digital)*Ln (Mining) demonstrated a significant negative coefficient at the 5 % level, supporting hypothesis H2b. The results suggest that with the advent of the digital economy, regulators and stakeholders are better equipped to monitor and manage mining activities, which mitigate resource monopolies and promote a more equitable distribution of benefits. This leads to a reduction in income inequality by ensuring that resource benefits are more fairly distributed across different segments of society.

The estimates of the mediating role of government expenditure between digital economy and income inequality are presented in columns III and IV. Based on the statistics in column IV, the interaction term (Digital)*Ln (Government) showed a significant positive coefficient at the 5 % level, confirming the validity of hypothesis H3a. This outcome may be attributed to the increased awareness of the government regarding the importance of fostering the digital economy for overall economic development. Consequently, the government would allocate more resources to support digital economy infrastructure and train talents within the digital economy industry. However, this could result in less investment in public services and social welfare, which would potentially affect lower-income groups and contribute to an increase in income inequality.

Columns V and VI display the results of the mediating role of remittances in the relationship between digital economy and income inequality. As shown in column VI, the interaction term (Digital)*Ln (Remittances) demonstrated a statistically significant negative coefficient, thus confirming hypothesis H4b. This finding was likely due to the traditional methods of sending money through banks or financial institutions, which often incur high fees and lengthy processing times. The rise of the digital economy and digital technology has enabled people to make faster and more cost-effective cross-border remittances through the Internet and mobile devices. This increased convenience and affordability allow more individuals to send remittances at lower costs, which reduces income losses due to high remittance fees and ultimately contributes to a reduction in income inequality.

### *4.4.2. Heterogeneity analysis*

EU28 countries exhibit distinct political systems and economic models, with some being ex-communist countries and others being capitalist countries. Ex-communist countries operate under a system of collective ownership and planned economies, where the government plays a prominent role. In contrast, capitalist countries lean towards market economies that emphasise private property rights and market mechanisms. These varying political and economic structures can lead to different impacts on digital economy and income distribution. By analysing the EU28 countries separately and considering their ex-communist or capitalist backgrounds, deeper insights can be derived into how the digital economy affects income inequality across different nations. This understanding is essential for formulating targeted policies and measures to promote digital economy and income equality. Among the 28 EU countries, 11 are ex-communist countries, including Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia,

**Table 4**
Heterogeneity analysis.

| | Ex-communist countries | | | | Capitalist countries | | | |
|---|---|---|---|---|---|---|---|---|
| | I | Mining | Government expenditure | Remittances | II | Mining | Government expenditure | Remittances |
| *Digitalit* | −3.7963*** | −3.2728*** | −2.9771*** | −3.0792*** | −4.9117*** | −4.2109*** | −5.8307*** | −3.0296*** |
| | (-8.4227) | (-8.4533) | (-7.7879) | (-8.4351) | (-10.3694) | (-10.8195) | (-9.2680) | (-9.5453) |
| *Ln(PGDPit)* | −0.1002*** | −0.1525*** | −0.0584*** | −0.0453 | −0.4502*** | −0.0782*** | −0.0522*** | −0.0148*** |
| | (-5.0027) | (-4.7004) | (-5.8858) | (-3.6555) | (-5.7296) | (-5.1227) | (-4.7475) | (-5.2310) |
| *Ln(Populationit)* | 2.0936*** | 1.3608*** | 1.6023*** | 2.5004*** | 0.2797** | 0.4388*** | 0.2968* | 0.2372** |
| | (8.0921) | (6.1463) | (6.4017) | (6.8035) | (2.5416) | (2.9985) | (7.9595) | (6.1154) |
| *Ln(Tradeit)* | −0.5796*** | −2.4718*** | −2.1235*** | −2.7911*** | −0.0934*** | −0.1682*** | −0.1054*** | −0.0615*** |
| | (-4.1807) | (-5.3911) | (-5.7336) | (-5.9794) | (-5.9213) | (-4.5552) | (-5.7591) | (-4.5861) |
| *FDIit* | −0.0030 | −0.0037 | −0.0002 | −0.0028 | −0.0001 | −0.0000 | −0.0000 | −0.0001 |
| | (-0.7921) | (-1.0713) | (-0.0600) | (-0.8040) | (-0.0708) | (-0.0035) | (-0.0203) | (-0.1960) |
| *Ln(Corruptionit)* | 1.1965*** | 0.6004*** | 0.4638*** | 0.9617** | 1.4246*** | 0.5869*** | 0.9428*** | 0.9070*** |
| | (4.7862) | (3.9082) | (3.4685) | (2.3983) | (5.2093) | (4.4727) | (4.0472) | (4.7547) |
| *Ln(Employmentit)* | 1.5036*** | 0.7383*** | 0.9746*** | 0.7120*** | 2.3604** | 1.9759*** | 1.1917* | 0.5265** |
| | (3.2084) | (3.8812) | (4.0002) | (4.7710) | (4.4906) | (4.3385) | (3.8161) | (2.3789) |
| *Ln(Miningit)* | | 0.7597* | | | | 0.3371** | | |
| | | (4.2414) | | | | (3.2560) | | |
| *Digitalit*Ln(Miningit)* | | −0.4500*** | | | | −0.3451** | | |
| | | (-3.7773) | | | | (-3.3345) | | |
| *Ln(Governmentit)* | | | −2.0085*** | | | | −2.7136*** | |
| | | | (-5.2777) | | | | (-5.0669) | |
| *Digitalit*Ln (Governmentit)* | | | 2.7907 | | | | 2.1527** | |
| | | | (3.9464) | | | | (5.0573) | |
| *Ln(Remittancesit)* | | | | 0.7877** | | | | 0.4389* |
| | | | | (2.0117) | | | | (2.4119) |
| *Digitalit*Ln (Remittancesit)* | | | | −0.2756 | | | | −0.8158* |
| | | | | (-0.8989) | | | | (-2.3293) |
| Constant | 3.0767*** | 4.0469*** | 4.8132 | 3.6750*** | 3.9474*** | 3.6882*** | 3.7817*** | 3.8280*** |
| | (12.0020) | (13.1937) | (5.2025) | (5.4975) | (11.0541) | (12.0180) | (10.3858) | (10.6779) |
| R-squared | 0.790 | 0.880 | 0.838 | 0.817 | 0.600 | 0.618 | 0.593 | 0.591 |

Note: t-statistics in parentheses, ***, **, and * indicate statistical significance at the 1 %, 5 %, and 10 % levels, respectively.

and Slovenia. The other 17 countries, namely Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, Norway, the Netherlands, Portugal, Spain, and Sweden, are classified as capitalist countries.

Therefore, the outstanding contributions of this study are mainly reflected in the following aspects: first, the relationship between the digital economy and income inequality in the EU economies had been deeply investigated, and the data showed that the digital economy has a dampening effect on income inequality, which fills the research gaps in this area for EU countries. Second, for the first time, the role of three moderating variables, namely mining activities, government expenditures, and remittances, were considered to deepen the knowledge of the mechanism by which the digital economy affects income inequality. From this, it was found that mining activities and remittances dampen income inequality under the influence of the digital economy, while government expenditures exacerbate income inequality. Finally, the heterogeneity among EU countries was set as an area of focus to better understand the impact of institutional differences on the relationship between the digital economy and income inequality. From this, it was found that the dampening effect of the digital economy on income inequality is significantly stronger in capitalist countries than in former communist countries. This multilevel research design allows this paper to make a comprehensive and unique contribution to the relationship between the digital economy and income inequality.

The results of the heterogeneity analysis in Table 4 (column I) reveal that the impact of the digital economy on income inequality varies between ex-communist and capitalist countries. Capitalist countries experience a more pronounced dampening effect of digital economy on income inequality. This difference may be attributed to the greater emphasis on market economies and competitive mechanisms in capitalist countries compared to ex-communist nations. The digital economy has created opportunities for a wider range of players in capitalist countries and has allowed more individuals and small and medium-sized enterprises to participate in economic activities and generate income. The open and competitive market environment in these countries fosters more opportunities and, consequently, contributes to the reduction of income inequality.

Additionally, the mechanism test results for mining indicate that mining activities in ex-communist countries, in the context of digital economy, have a more significant impact on reducing income inequality compared to capitalist countries. This difference may be explained by the presence of abundant natural resources such as oil, gas, and ores in some ex-communist countries. In the digital economy, the extraction and export of these resources continue to yield substantial economic benefits. The scarcity and high value of these resources also often result in high incomes from the resource sector, which can significantly influence overall national income and, consequently, income inequality.

Regarding government spending, amid the growth of the digital economy, state spending in ex-communist countries was found to have a facilitating effect on income inequality, albeit not significantly. In contrast, government spending in capitalist countries significantly contribute to income inequality in the presence of digital economy. This distinction may arise from the fact that digital economy advancement can lead to the emergence of new industries and sectors that may not fully align with the traditional economic structure of ex-communist countries. Capitalist countries may thus allocate more resources to develop and support industries related to the digital economy, such as technological innovation, digital platforms, and entrepreneurial ecosystems. This increased investment by capitalist countries may lead to a more substantial impact of government spending that contributes to income inequality.

Finally, remittances from capitalist countries in the digital economy era also reduced income inequality more significantly than remittances from ex-communist countries. This difference can be attributed to the fact that capitalist countries usually possess more advanced and extensive financial technologies and digital payment systems within the digital economy. As a result, individuals and businesses in capitalist countries can conduct cross-border remittances and financial transactions more easily, leading to reduced transfer costs and barriers that ultimately narrows the income inequality gap.

## 5. Conclusion

This study conducted a comprehensive assessment of the impact of digital economy on income inequality in EU28 countries from 2015 to 2021. By employing fixed effects models, placebo tests, and variable substitution, the relationship between digital economy and income inequality was explored while controlling for other influencing factors, including trade, FDI, corruption, population size, and employment. The empirical findings support the hypothesis that the digital economy has a dampening effect on income inequality, and this relationship was found to be linear. Moreover, by incorporating mediators into the model, three mechanisms through which digital economy affects income inequality, namely mining, government spending, and remittances, were identified. Additionally, the study revealed that population size, corruption, and employment were the main factors that exacerbate income inequality, while economic development, trade, and FDI had a mitigating effect on income inequality. Furthermore, to assess the heterogeneity of the digital economy's impact, the 28 EU countries were divided into ex-communist and capitalist countries based on their political systems. The results indicated that the suppressive effect of the digital economy on income inequality was significantly stronger in capitalist countries than in ex-communist countries. Additionally, mining in the digital economy era was found to play a more significant role in reducing income inequality in ex-communist countries compared to capitalist countries. Conversely, government spending amid digital economy significantly promotes income inequality, while remittances have a more pronounced impact in suppressing income inequality in capitalist countries compared to ex-communist countries.

These findings offer valuable insights into digital economy and its potential for reducing income inequality in the EU28. This study suggests that as the digital economy develops, income inequality tends to decrease in these countries. Therefore, to promote digital economy and address income inequality, EU28 governments can take several strategic measures. First, by encouraging innovation and RandD in the digital technology sector, supporting start-ups, and investing in high-growth and high-value-added digital industries, governments can foster a conducive environment for a digital economy. Second, efforts to strengthen the development of digital infrastructure, including broadband networks, data centres, and cloud computing will provide a solid technological foundation for the

digital economy's advancement. Third, providing comprehensive digital skills training and education will empower individuals to adapt to the demands of the digital economy, which increases employment opportunities and help narrow the income gap.

## Research limitations and recommendations

Despite the important findings of this study in exploring the impact of the digital economy on income inequality in EU countries, there were some limitations. First, the geographical and temporal scope of the study was limited to the EU economies and only considered data from 2015 to 2021, which may limit the generalisability of the findings. Second, the availability and quality of data were potential limitations, as there may be differences in the method and quality of data collection in different countries, which may affect the accuracy of the study. In addition, although the study concluded that the digital economy has a dampening effect on income inequality, a causal relationship was not established, and other variables or confounding factors that were not considered may have had an impact on the findings. To remedy these limitations, future research could improve the generalisability of the findings by expanding the scope of the study to consider data from more regions and over a longer period. In addition, a deeper exploration of the mechanisms through which moderating variables such as mining activities, government expenditures, and remittances work may require more detailed and specific data. Also, other factors that may influence the relationship between the digital economy and income inequality could be considered to establish causality more accurately. Finally, the heterogeneous impact of the digital economy on different types of countries could be explained better by delving into specific institutional, policy, and cultural aspects to explain the differences. By continuing to conduct in-depth research and improving the research methodology, the reliability and applicability of the study can be enhanced to provide more valuable references for future research and policy formulation in related fields.

## Availability of data

Authors provide data on request.

## Statement of interests

All authors apply unanimously. We are only interested in contributing to this journal and will not contribute to other journals or international conferences. We promise to only contribute our research results to your journal.

## CRediT authorship contribution statement

**Li Tian:** Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Yijun Xiang:** Supervision, Software, Resources.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix

### *A1 Multicollinearity test*

| Variable Name | VIF | 1/VIF |
|---|---|---|
| *Trade* | 3.79 | 0.263852 |
| *Population* | 3.46 | 0.289017 |
| *Digital* | 3.28 | 0.304878 |
| *Corruption* | 3.11 | 0.321543 |
| *Employment* | 1.95 | 0.512028 |
| *Pgdp* | 1.26 | 0.794313 |
| *FDI* | 1.05 | 0.951947 |
| Mean VIF | 2.55 | |

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