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Income Inequalities in the Accelerating Digital Era: Evidence from EU Countries and COVID-Time

Summary: Many research state that digitalization is mainly an opportunity, now more than ever. Digital firms are more productive, employ more skilled workers, and foresee more employment growth opportunities ahead. In 2020, the combined health and economic shocks have, however, accelerated the technology-driven displacement of jobs, which can exacerbate existing inequalities in the coming years. The goal of this paper is to analyze changes in the scale of income inequalities over the last five years, ending in 2021 with respect to the pre-existing inequalities in access to ICTs (connectivity), differences in digital skills (human capital), integration of digital technology in enterprises and digital public services in EU countries. Our research indicates that in the short-term, the degree of inequality in EU27 nations grew more in countries with greater connectivity, as measured by access to broadband Internet. However, only the integration of digital technology in businesses and fundamental access to the Internet were linked to a greater reduction in the Gini index from 2017-2021.

Keywords: Inequalities, Technological change, Digital economy.

JEL: D31, E24, O33.

The COVID-19 pandemic has caused organizational upheaval on a massive scale. On the one hand, the organizational response to the COVID-19 pandemic has surfaced potential success stories, such as the move to telehealth, the increase in flexible work arrangements, and the intensification of digitalization across many sectors (Suphachai Chearavanont 2020; Judd E. Hollander and Brendan G. Carr 2020). On the other hand, the pandemic has profoundly disrupted work and has revealed how many organizations have struggled to adapt to new technologies (Andre Dua et al. 2020). The EU States have been advancing in their digitalization efforts but still struggle to close the gaps in digital skills, the digital transformation of small and medium enterprises (SMEs), and the roll-out of advanced 5G networks (European Commission, DESI 2022).

Before COVID-era it was already proved that digital technologies are altering business models and how firms compete and grow. Digitalization is also reshaping the market structure. The potential economic gains from digital technologies are enormous, but with new opportunities come new challenges. The distribution of both capital and labor income has become more unequal, and income has shifted from labor to capital. Within economies, income and wealth inequalities have risen as digitalization has reshaped markets and the world of business and work. Technological change is not the sole reason for the rising inequalities. Globalization and job dislocations have also been factors behind rising inequality, but technological change and policy failures seem to be a much more important part of the story. IMF research finds that, in advanced economies, technological change has contributed about twice as much as globalization to the decline in the labor-income share (International Monetary Fund 2017). Then, the shock related to the COVID-19 pandemic called "*the great accelerator*" in fast-tracking the existing global trends towards embracing modern emerging technologies ushering in transformations in lifestyle, work patterns, and business strategies, changes the development path (Joseph Amankwah-Amoah et al. 2021). The way the new technologies are deployed across industries and firms has, however, important implications for their economic impact and the distribution of rewards.

Therefore, the aim of this paper is to analyze changes in the scale of income inequalities in the last five years, ending in 2021 with respect to the pre-existing inequalities in access to ICTs (connectivity), differences in digital skills (human capital), integration of digital technology in enterprises and digital public services in EU countries. More specifically our explanatory study investigates the factors related to the uneven digital transformation and aims at indicating which of the digital areas were the drivers of the deepening income inequalities during the COVID-19 pandemic. We contribute to the literature on income disparities by investigating determinants of income distribution in the extraordinary period of the pandemic. Based on the obtained results, we also discuss the potential consequences of (possibly) deepening income inequalities for future EU development.

The extensive literature on COVID-19 and accelerating digitalization (e.g. Elisabeth Beaunoyer, Sophie Dupere, and Matthieu J. Guitton 2020; Matteo Sostero et al. 2020; Amankwah-Amoah et al. 2021; Mauro Caselli and Andrea Fracasso 2021; Samer Faraj, Wadih Renno, and Anand Bhardwaj 2021; Anupam Nanda, Yishuang Xu, and Fangchen Zhang 2021) examines a range of issues including uneven access to digital infrastructure, the limits of digitalization, the brittleness of headlong digitalization, panoptical surveillance, acceleration of e-commerce, the emergency digitalization of education, and new employer-employee relationships. There is still a lack of research on digital disparity issues related to income distribution and highlighting the relationship between technology and social concerns in times of pandemic. To the best of our knowledge, we found only a few papers focusing on economic inequality in the COVID-19 era (e.g., Abi Adams-Prassl et al. 2020; Nikolay Angelov and Daniel Waldenström 2021; Luca Bonacini, Giovanni Gallo, and Sergio Scicchitano 2021; Andrew E. Clark, Conchita D'Ambrosio, and Anthony Lepinteur 2021; Sinem Hacıoğlu-Hoke, Diego R. Känzig, and Paolo Surico 2021; Dania V. Francis and Christian Weller 2022; Borja Gambau et al. 2022; Carmen Aina et al. 2023). Among them, only the paper by Francis and Weller (2022) analyzes the link between wealth, reliable internet and electronic device availability, remote learning time, race, and ethnicity in the US. In turn, Bonacini, Gallo, and Scicchitano (2021) explore the potential consequences in the labor income distribution related to a long-lasting increase in working-from-home feasibility among Italian employees. Our study is a contribution to the literature that examines explicitly income inequality from the digital divide perspective, in a larger context – EU27 countries and from a 5-year perspective (in 2017-2021).

We reveal that even though the immediate labor market impacts of COVID-19 differ considerably across countries, CEE countries suffered more falls in earnings than EU14. It could be the effect of the more likely loss of jobs due to less advancement in digitalization and a small share of tasks that can be done from home. Our research indicates that in the short-term, the degree of inequality in EU27 nations grew more in countries with greater connectivity, as measured by access to broadband Internet. However, only the integration of digital technology in businesses and fundamental access to the Internet were linked to a greater reduction in the Gini index from 2017-2021. These fundamental outcomes demonstrate the impact of digital technology and the Internet on income inequality in the EU27.

The remainder of this paper is organized as follows. We begin with a literature review on digital transformation about productivity and income distribution. Then, the next section presents the income inequalities and digitalization trends in EU27 in 2017-2021. In the following section, we describe the data collected and used in the empirical analysis. Next, we present the econometric approach and the results of our research. The last section provides conclusions and directions for further research.

1. Uneven Diffusion of New Technologies and Widening Income Gaps - Literature Review

Technology has long been identified as one of the drivers of income inequality – together with globalization and other organizational and institutional factors. Research on the technology impact on inequalities has largely emphasized the effects of skilled-biased technological change with large wage disparities between skilled and unskilled workers (David H. Autor 2014; Autor et al. 2017; Daron Acemoglu and Pascual Restrepo 2018). Demand has shifted away from routine, middle-level skills that are more vulnerable to automation. Job markets have seen an increasing polarization that manifests itself as a digital divide between groups and regions with low-skilled, low-wage labor and a higher risk of unemployment, and groups and regions with high-skilled, high-wage labor and a low risk of unemployment. The imbalance between skills demand and supply have fueled income inequality, by increasing the wage premia on higher-level skills (Autor 2014; Eric A. Hanushek et al. 2015).

Other research argues that the growing importance of digital innovation – new products and processes based on software code and data – has increased market rents, which benefit disproportionately the top income groups (Dominique Guellec and Caroline Paunov 2017; Jason Furman and Peter Orszag 2018). The rise in market rents is partly the result of increasing returns to scale that favor concentrated market structures. The benefits of the new technologies have not been diffusing widely across firms. They have been captured for the most part by a relatively small number of larger firms (Jose Azar, Ioana Marinescu, and Marshall I. Steinbaum 2017; Diego Comin and Marti Mestieri 2018; Gauti B. Eggertsson, Jacob A. Robbins, and Ella Getz Wold 2018; Organisation for Economic Co-operation and Development - OECD 2018; Phillippe Aghion et al. 2019).

This weakening of competition related to market frictions and barriers prevents a broader diffusion of the new technology causing a persistent rise in productivity[1] and profitability gaps between firms. Consequently, markets have shifted toward more monopolistic structures, giving rise to higher economic rents where "winner-takes-most" is prevalent (Robert H. Frank and Philip J. Cook 2013). Digital technologies offer here first-mover advantages, scale economies, network effects, and leverage of "big data" that encourage the rise of dominant firms. In the digital era, the usual technological gap between leaders and followers is accentuated, as exemplified by how R&D expenditure is concentrated in a few firms. This trend is reinforced by globalization which extends the scale of economies by facilitating access to markets worldwide. Increasing market power and corporate ossification with declining business dynamism as measured by new firm formations impact innovation diffusion and matter greatly for income distribution (Zia Qureshi 2019).

Moreover, the more knowledge, data, and software are deployed at scale across networks, the lower the unitary cost. Earnings inequality is in part driven by rising inequalities between firms – which then translates into inequalities among workers within firms and those working for the same employer – men vs. women, young vs. old, new hires vs. senior employees, etc. (Jae Song et al. 2015). Guellec and Paunov (2017) identify two mechanisms linking market concentration to executive pay. First is compensation for higher risks. In addition to increased concentration, today's markets feature more volatility as there are more players that can use technology to disrupt (and steal) the market. This means that the risk of failure (or threat of liquidation) in such juicy markets increases, i.e., if you arrive second, you get nothing. CEOs are compensated for taking on the extra risk and for protecting the firm's market position. The second one is managerial rent extraction, which could be the result of inadequate governance, with managerial power increasing in the few global corporations that concentrate on the market (Wolfgang Keller and William W. Olney 2017).

Failures in competition policies have reinforced the technology-driven dynamics producing more concentrated market structures. Together with weaknesses in worker bargaining power due to a decline in unionization, and erosion of minimum wage laws, production shifted toward firms and processes using more capital (tangible and intangible) and less labor.

Then, the COVID-19 pandemic changed the face of technological development forever. Technology use has increased dramatically due to business demands for higher agility and flexibility (Ahmed Elragal, Moutaz Haddara, and Eli Hustad 2020). The smaller firms and lagging regions or even countries do not absorb the new digital technology as fast as big companies and needed to cope with the disruption posed by the pandemic. Consequently, the combined health and economic shocks have only deepened the concerns about technology-driven displacement of jobs and growing income inequality.

The acceleration of digitalization, while presenting many positive aspects, exposes a persistent digital divide that leaves socially and technologically marginalized

[1] For example, between 2001 and 2013, in OECD economies, labor productivity among frontier firms rose by around 35%; among non-frontier firms, the increase was only around 5% (Dan Andrews, Chiara Criscuolo, and Peter N. Gal 2016).

populations – rural, immigrant, uninsured, low-income, digitally illiterate, and older populations – with even more limited access to essential services. The term "digital divide" refers to the gap between individuals, households, businesses, and geographic areas at different socio-economic levels regarding both their opportunities to access ICTs and their use of the Internet for a wide variety of activities. This digital divide raises several questions about the technology and institutional issues with strong social justice which is even more important in the wake of the pandemic and the accelerating unequal technology-driven structural shift.

2. Income Inequalities and Digitalization Trends in EU27 Countries in 2017-2021

Over the past decades, the increase in economic inequalities has largely been driven by a rise in income and wealth accruing at the top of the distribution. In international comparison, the concept of *gross domestic product* (GDP) was commonly used to compare levels of economic welfare across countries. However, a country with a large GDP but extensive capital depreciation and foreign outflows does not have much income to distribute to its residents and citizens. Therefore, is better to focus on the distribution of national income and wealth, i.e., how the different percentiles of the distribution – from the bottom to the top – evolve over time and across countries. In our research, we overcome this limitation by referring to the World Inequality Database (WID.world) which combines different data sources: national accounts, survey data, fiscal data, and wealth rankings to show the evolution of all income or wealth levels, from the bottom to the top. More specifically we will study the Gini coefficient which is a measure of statistical dispersion intended to represent the income inequality within a nation or social group and show the previous trends in the top 1% share, top 10% share, and top 10% to bottom 50% ratio – all based on data retrieved from WID database. Moreover, to avoid data distortion by large social transfers related to COVID-policy, we will refer to categories so-called pretax, which means income before taxes and transfers corresponding to "market income" (gross wages and salaries with self-employment income and capital and property income). Income after taxes and transfers corresponds to "disposable income" (market income with social security cash transfers and private transfers reduced by income tax).

Income inequality has risen the most in CEE countries in 2017-2021 (Figures 1 and 2), a period of accelerating boom in digital technologies (Figure 3). Over the last five years, ending in 2021, European disposable income inequality, as measured by the broadest measure of inequality (the Gini index), was the highest in Bulgaria and Romania, but the lowest in the same part of Europe – in Czechia and Slovakia, and additionally in Sweden. The mean value of Gini in 2017-2021 was higher in CEE countries (0.475) than in EU14 (0.451) and EU27 (0.456). The top 10% to bottom 50% ratio has increased the most in CEE countries from 9.284 in 2017 to 9.778 in 2021 and decreased in EU27 and EU14 (respectively from 8.544 and 8.321 to 8.502 and 8.127).

Notes: The means for EU27, CEE, and EU14 were calculated as a population-weighted average.

Source: Own elaboration based on data from the World Inequality Database (WID 2022)[2].

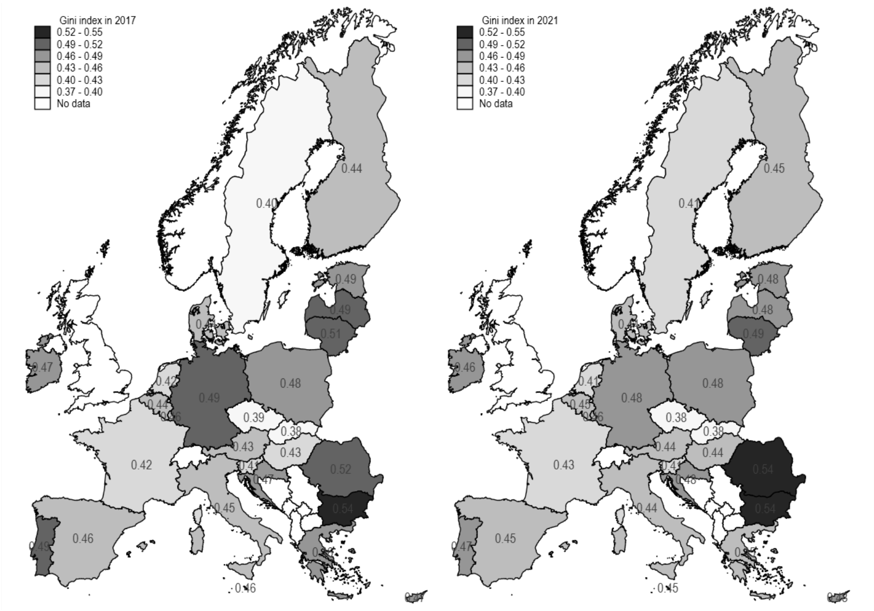
Figure 1 Income Inequalities in EU Countries in 2017-2021

The largest increase in the scale of income inequalities measured by the Gini index between 2017 and 2021 was recorded for Romania (from 0.52 to 0.54)[3]. Other big countries like France, Sweden, Finland, Belgium, Austria, and Hungary also recorded a deterioration in the Gini index. In turn, Germany, Spain, Portugal, Italy, and Ireland decreased their income inequality in the analyzed period (Figure 2). It is worth remembering, however, that the Gini coefficient can be misleading when used to make political comparisons between large and small countries.

Digitalization is seen as the main factor in increasing the Union's resilience and reducing external dependencies. Despite the progress across key digital areas, there are still areas and countries requiring priority action. Between 2017 and 2021 the largest increase in the Digital Economy and Society Index (Figure 3) were recorded for Denmark (+0.19), the Netherlands (+0.17), Ireland (+0.16), and Finland and Sweden (+0.15), and the lowest for Romania (+0.08), Bulgaria and Latvia (+0.09). Looking only at the COVID-19 era, EU states have been advancing in their digitalization efforts but still struggle to close the gaps between countries in digital skills, the digital trans formation of SMEs, and the roll-out of advanced 5G networks. According to the data,

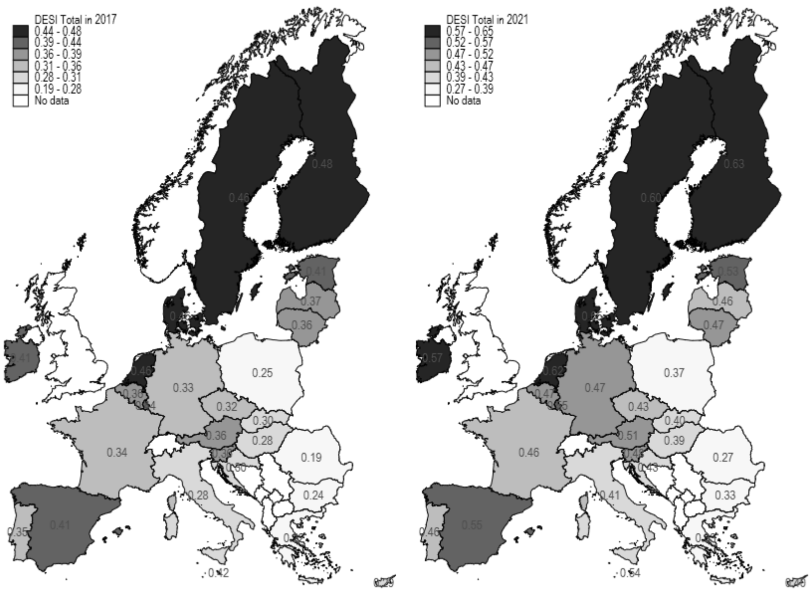
[2] **World Inequality Database.** 2022. https://wid.world/ (accessed July 10, 2022).

[3] Gini index is a number between 0 and 1, where 0 corresponds with perfect equality (where everyone has the same income) and 1 corresponds with perfect inequality (where one person has all the income, and everyone else has zero income).



Source: Own elaboration based on data from the WID database (2022).

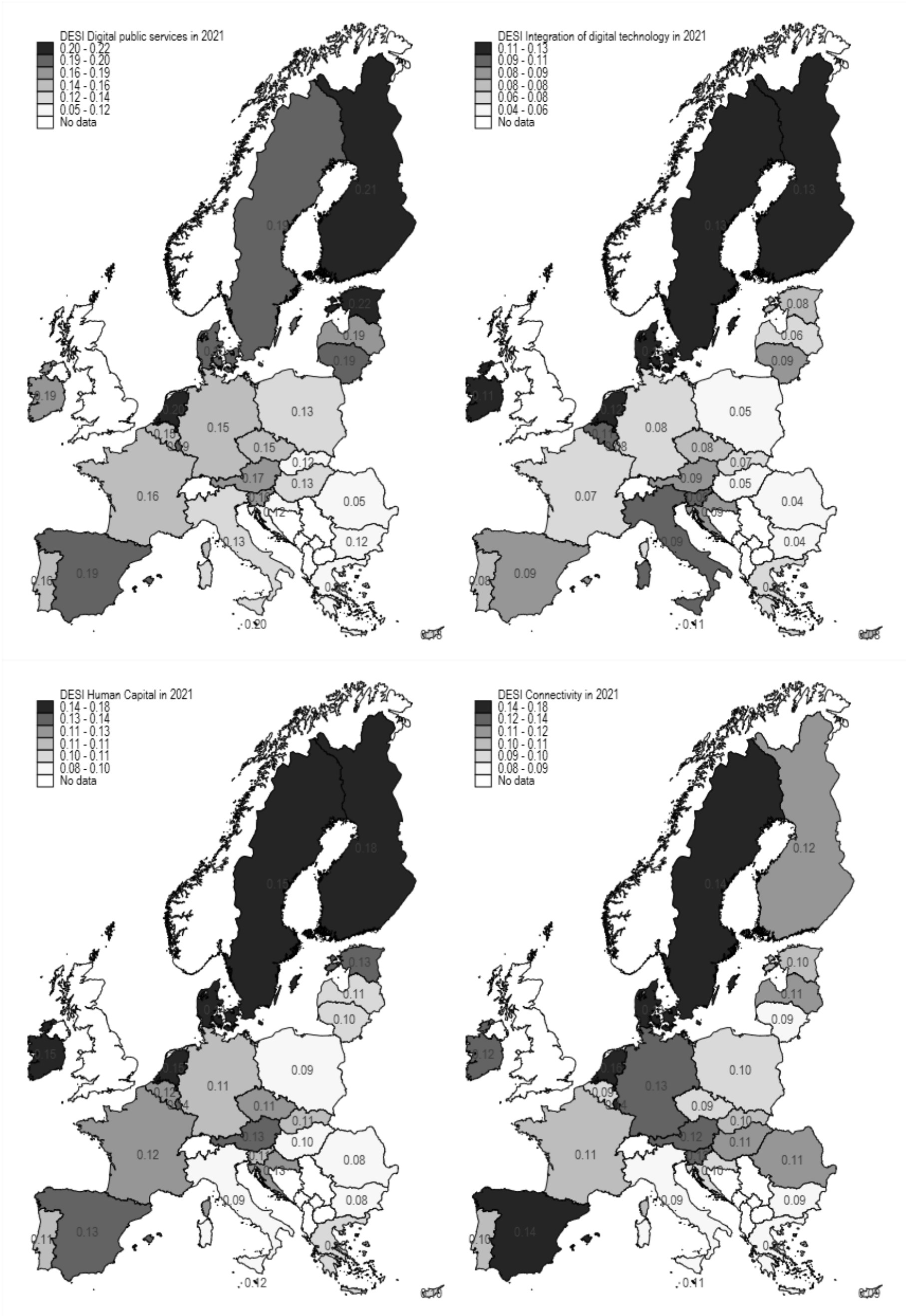
Figure 2 Gini Coefficient in EU Countries, 2017 and 2021



Source: Own elaboration based on data from the DESI database (WID 2022).

Notes: Score from 0-1.

Figure 3 Digitalization Trends in EU Countries, 2017 and 2021



Source: Own elaboration based on data from the DESI database (WID 2022).

Notes: Score form 0-1.

Figure 4 DESI Key Areas in EU Countries in 2021 Finland was leading in human capital, followed by Sweden, the Netherlands, and Denmark (Figure 4). Whereas Italy, Romania, and Bulgaria rank the lowest. In connectivity, Denmark has the highest score, followed by the Netherlands and Spain. Greece and Bulgaria have the weakest performance in this dimension. The top performers in the integration of digital technologies in 2021 were Finland, Denmark, and Sweden. In turn, Bulgaria, Hungary, and Romania show the weakest performance. In digital public services, Estonia, Denmark, and Finland remain the top performers, while Romania, Greece, and Hungary have the lowest score (European Commission 2021)[4] (Figure 4).

The next section checks which of the digitalization factors remain, robust predictors of the Gini coefficient, when econometric tools are employed.

3. Data

In the next steps of our study, we investigate the digitalization drivers explaining income inequalities in 2017-2021. This 5-year time series consists of two parts – three years before the pandemic with dynamic technological change and two years of the pandemic with accelerating digitalization. Following the literature review on digital transformation and its impact on income distribution, we will concentrate on a broad set of digital indicators as potential determinants of the observed discrepancies. We apply here the term "digital transformation" referring to the selected indicators of the Digital Economy and Society Index (DESI) over the period of 2017-2021.

In the set of independent variables, we include the DESI sub-indexes of Human capital (1), connectivity (2), digital public services (3), and integration of digital technology (4). The first one (human capital) is composed of the share of the population with at least basic and above digital skills, the share of the population with at least basic digital content creation skills, the share of ICT specialists in employment aged 15-74, the share of female ICT specialists, the share of enterprises providing ICT training, and the share of ICT graduates. The second one (i.e., connectivity) is based on the shares of households with overall fixed broadband take-up, the shares of households with at least 100 Mbps fixed broadband take-up, the shares of households with at least 1Gbps take-up, with fast broadband (NGA) coverage, the shares of households with fixed, very high capacity network (VHCN) coverage, the shares of households with fiber to the premises (FTTP) coverage, assigned 5G spectrum as a % of total harmonized 5G spectrum, 5G coverage as % of populated areas, the share of mobile broadband take-up, and broadband price index. The third one (public digital services) is based on the share of e-Government users among Internet users, pre-filled forms, digital public services for citizens, digital public services for businesses, and open data indicators. Finally, the last sub-index (integration of digital technology) is based on the share of SMEs with at least a basic level of digital intensity, selling online, having e-commerce turnover, and selling online cross-border, the share of enterprises sharing electronic information, present in social media, and using big data, cloud, AI, e-Invoices, and the share of enterprises having medium/high intensity of green action

[4] **European Commission.** 2022a. The Digital Economy and Society Index (DESI). https://digital-strategy.ec.europa.eu/en/policies/desi (accessed July 12, 2022).

through ICT. Additionally, the level of Internet access among EU households was included in the analysis to control for the basic policy of digital expansion. To control the analysis with this indicator, we aim to check if basic Internet access is still a key factor in digital development. The lack of its significance can confirm that more advanced technologies are needed to solve the problem of inequalities. The dataset is summarized in Table 1.

Table 1 List of Variables Used in the Estimation

Variable	Description	N	Mean	SD	Min	Max
Gini coefficient	The index ranges from 0 to 1; the higher the index the more unequal the income distribution	135	0.455	0.0396	0.376	0.545
DESI human capital[5] *DESI_HC*	Measure "internet user skills" and "advanced skills and development" across the EU to ensure people are equipped for the digital decade, this DESI sub-index ranges from 0 to 1; the higher the index the better performance in Human capital.	135	0.0846	0.0246	0.0317	0.180
DESI connectivity[6] *DESI_CONN*	Monitor connectivity throughout the EU, measuring both supply and demand of fixed and mobile broadband; this DESI sub-index ranges from 0 to 1; the higher the index the better performance in connectivity.	135	0.138	0.0399	0.0185	0.216
DESI digital public services[7] *DESI_DPS*	Monitor indicators of digital public services in the EU to ensure citizens and governments are enjoying the full potential of this technology; the DESI sub-index ranges from 0 to 1; the higher the index the better performance in public services.	135	0.0700	0.0237	0.0253	0.134
DESI integration of digital technology *DESI_IDT*	Monitor the integration of the new technologies in business and eCommerce; the DESI sub-index ranges from 0 to 1; the higher the index the better performance in integration.	135	0.455	0.0396	0.376	0.545
Internet access	Level of internet access among household (in percentage point)	135	87.87	6.433	67	99
GDP per capita	Constant prices from 2017	135	27180.89	17362.01	6120	84490
Labor productivity	Hourly labor productivity in constant prices from 2017	134	114.33	14.34	83.18	174.22

Notes: The study was conducted for 27EU countries, namely: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden.

Source: Own elaboration. All data were collected from European Commission (2022) for details on the DESI and a from the WID database (2022).

Table 2 presents the correlations between different measures of income inequalities and the Digital Economy and Society Index (DESI) and its sub-indexes tracking the EU countries' progress in digital transformation in 2017-2021. Our findings are in line with common thinking, emphasizing the possible impact of digitalization on

[5] **European Commission.** 2022b. Human Capital and Digital Skills in the Digital Economy and Society Index. https://digital-strategy.ec.europa.eu/en/policies/desi-human-capital (accessed July 13, 2022).
[6] **European Commission.** 2022c. Broadband Connectivity in the Digital Economy and Society Index. https://digital-strategy.ec.europa.eu/en/policies/desi-connectivity (accessed July 13, 2022).
[7] **European Commission.** 2022d. Digital Public Services in the Digital Economy and Society Index. https://digital-strategy.ec.europa.eu/en/policies/desi-digital-public-services (accessed July 13, 2022).

income inequality reduction. The largest negative correlations with the Gini index were recorded for two DESI sub-indexes – human capital and integration of digital technology (both -0.410). The top 10% to bottom 50% income ratio and the top 10% share of income were, in turn, also negatively associated with human capital (respectively at levels -0.464 and -0.410) and integration of digital technology (-0.459 and -0.418). The largest negative correlation with the top 1% share of income was recorded, however, only for the integration of the digital technology sub-index (-0.426). The differences in the correlations between inequality indicators and technological advancement are so small that we decided to choose for further analysis the broadest measure of inequality – the Gini index. The advantage of the Gini index is that inequality of the entire income distribution can be summarized by using a single statistic that is relatively easy to interpret since it takes values between 0 and 1. This allows for a comparison among countries with different population sizes.

Table 2 Correlation Matrix (2017-2021)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Gini coefficient	1.000									
(2) Top 10% to bottom 50% income ratio	0.985	1.000								
(3) Top 10% share of income	0.963	0.961	1.000							
(4) Top 1% share of income	0.716	0.746	0.846	1.000						
(5) DESI TOTAL	-0.330	-0.381	-0.345	-0.329	1.000					
(6) DESI human capital	-0.410	-0.464	-0.410	-0.366	0.855	1.000				
(7) DESI connectivity	-0.085	-0.081	-0.097	-0.076	0.726	0.394	1.000			
(8) DESI digital public services	-0.259	-0.323	-0.281	-0.276	0.934	0.755	0.595	1.000		
(9) DESI integration of digital technology	-0.410	-0.459	-0.418	-0.426	0.876	0.797	0.507	0.731	1.000	
(10) Internet access	-0.354	-0.390	-0.346	-0.286	0.757	0.691	0.624	0.637	0.661	1.000

Source: Own elaboration. All data were collected from European Commission (2022) for details on the DESI and a from the WID database (2022).

4. Empirical Strategy and Results

Our study aims at identifying digitalization factors related to the Gini coefficient in the EU countries and at investigating how digitalization and technological advancement determine income inequality reduction in 2017-2021. Therefore, we estimate eight sets of models – in Models 1-4, the levels of Gini in 2017-2021 are the dependent variable and in Models 5-8 – the change in Gini index to the previous year (in 2017-2021) in percentage points is the dependent variable. To assess the economic importance of independent variables included in the analysis, we calculated our models using the OLS method (Ordinary Least Square – Models 1 and 5). Then, to check if the obtained results are robust, we included random effects (Models 2 and 6), country-fixed effects (Models 3 and 7), and country and year-fixed effects (Models 4 and 8). The set of independent variables was introduced in the previous section. As a robustness check, we conducted an analysis where the top 10% share and the ratio of the top 10% to the bottom 50% were used as dependent variables. The results of the analysis show that there were no significant differences. The detailed results are presented in the Appendix Tables A1 and A2.

The fact that we analyze cross-national differences in income inequalities poses some methodological challenges. First, the EU countries might substantially differ in terms of their policies toward digitalization and institutional settings (e.g., different social capital, historical background, etc.) which can impact uneven income distribution before the state intervention, and then their steps to counteract the COVID-19 pandemic. This in turn might be a relevant factor in shaping the income distribution and the omission of country-fixed effects could lead to omitted variable bias. However, by including country-fixed effects (FEs), a large part of the variation between countries might be ruled out from the analysis, leading to less insightful findings on the independent variables of interest. Moreover, estimates from an FE approach (intercepts and coefficients) relate specifically to the set of countries included in the sample and cannot be generalized out of the sample. As an example, FE estimates from a dataset including respondents from the original 14 European Union member states could not be applied to describe outcomes for the 12 new member states with their very different institutional and historical contexts. Given the exploratory character of our study, we decided not to include country FEs in the basic specification and consider them in the robustness check only. Second, for the multilevel country data case, there are problems when the number of countries is small – which is the usual situation. The intuition is straightforward: in general, desirable properties of regression model parameter estimates such as consistency and efficiency are contingent on sample sizes being “large”. In particular, a large number of groups (countries) is needed in order to estimate country effects reliably. The caveat applies both to the “fixed” parameters associated with country-level explanatory variables (and individual-country-level interactions) and to the variances of random country-specific parameters (intercepts and slopes). It is a generic problem that affects all regression modeling approaches (Mark L. Bryan and Stephen P. Jenkins 2013). Therefore, in the robustness check, we also included country random effects models where the regression intercept is a population average, and deviations from this average are assumed to be uncorrelated with country-level variables included in the model. With these assumptions, the random effects (REs) results can be generalized to other countries with different policies and institutions. For example, the estimate of the effects of digitalization on inequalities based on the old EU countries may be applied to possible legislative changes in the new member states.

The results of the econometric analysis are displayed in Table 3. Model 1 examines the Gini index from 2017-2021 and reveals a positive and statistically significant association (at least at the 10% level) between income inequality and connectivity in both the random effects and fixed-time effects models. Conversely, the Gini variable exhibits a negative correlation with the integration of digital technology and internet access (in the OLS model) and digital public services (in the fixed effects model). Additionally, we discovered a robust correlation between the Gini index and productivity and GDP *per capita* controls. When we analyzed the Gini change from the previous year, the coefficient for the integration of digital technology is no longer significant, and the digital public services exhibit a statistically significant (at least at the

10% level) negative correlation (in the OLS and random effects models) with the Gini change, with alterations in the coefficients' magnitudes. Model (7) also indicates a significant negative relationship (at the 10% level) between connectivity and Gini change.

A positive relationship between Gini and connectivity in Model 1 might be perceived as surprising. Nevertheless, there might be at least two reasons for such an association. First, connectivity means access to broadband Internet. Europe has done well in expanding access to broadband. At least 69 percent of households have access to broadband in every European region, and over 90 percent of households are fully connected in most regions (World Bank 2019, 2020). Despite progress over the last few years, broadband coverage remains uneven between rural and urban areas, with large differences especially when it comes to VHCNs (Very High-Capacity Networks). In connectivity, Denmark has the highest score, followed by the Netherlands and Spain. Belgium and Estonia have the weakest performance on this dimension in the DESI (DESI Digital Infrastructure European Commission 2022). Secondly, the broadband connectivity target is easier accessible for wealthier households and could offer them more opportunities and increase even more income inequalities.

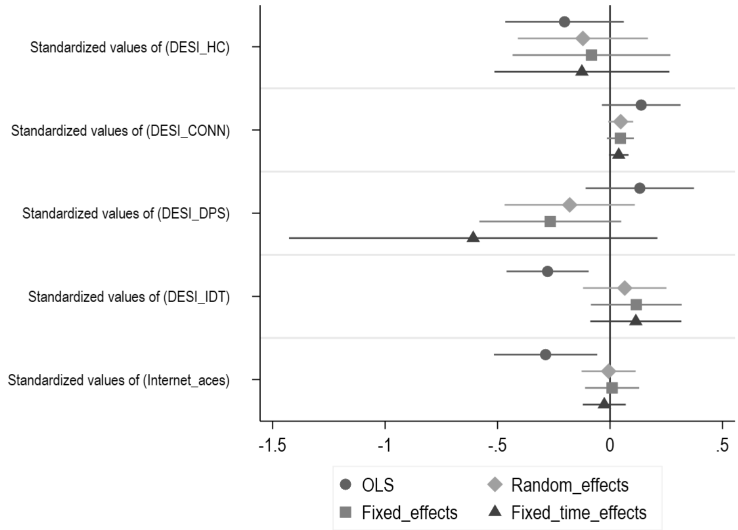
Table 3 Regression Results

Specification	**OLS**	**Random effects**	**Fixed effects**	**Fixed-time-effects**	**OLS**	**Random effects**	**Fixed effects**	**Fixed-time-effects**
Model #	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. variable	*Gini index*	*Gini index*	*Gini index*	*Gini index*	*Gini change*	*Gini change*	*Gini change*	*Gini change*
DESI_HC	-0.348 (0.229)	-0.207 (0.254)	-0.142 (0.293)	-0.215 (0.325)	5.695 (7.565)	5.695 (4.763)	11.44 (45.35)	68.66 (45.20)
DESI_CONN	0.223 (0.142)	0.0766* (0.0454)	0.0742 (0.0470)	0.0623* (0.0342)	3.325 (6.076)	3.325 (4.368)	-21.01* (10.79)	-13.79 (8.759)
DESI_DPS	0.132 (0.121)	-0.178 (0.147)	-0.264* (0.153)	-0.605 (0.396)	-13.55** (5.758)	-13.55*** (1.856)	23.46 (33.00)	139.3 (83.86)
DESI_IDT	-0.464*** (0.154)	0.110 (0.158)	0.196 (0.164)	0.192 (0.165)	2.232 (6.477)	2.232 (5.169)	26.10 (30.03)	40.95 (34.14)
Internet_access	-0.00177** (0.000715)	-3.82e-05 (0.000378)	5.81e-05 (0.000360)	-0.000158 (0.000286)	0.0483 (0.0302)	0.0483 (0.0328)	-0.0391 (0.0729)	0.0650 (0.0735)
GDP_per capita	3.51e-07** (1.67e-07)	-4.56e-07 (3.39e-07)	-5.53e-07 (4.46e-07)	-5.32e-07 (4.76e-07)	-8.08e-07 (5.32e-06)	-8.08e-07 (5.25e-06)	-0.789 7.79e-05 (8.48e-05)	
Productivity	0.000840*** (0.000149)	0.000219 (0.000166)	0.000220 (0.000185)	0.000225 (0.000178)	0.00738 (0.00667)	0.00738 (0.00659)	-0.0187 (0.0288)	
Constant	0.539*** (0.0513)	0.479*** (0.0331)	0.472*** (0.0340)	0.537*** (0.0612)	-4.357 (2.637)	-4.357 (2.932)	-1.251 (7.071)	-32.16** (14.99)
Country FE			✓	✓			✓	✓
Year FE				✓				✓
Observations	134	134	134	134	107	107	107	107
R-squared	0.321		0.070	0.104	0.126		0.054	0.132
Number of countries		27	27	27		27	27	27

Notes: Robust standard errors are reported in parentheses. Asterisks denote significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. A list of variables is described in Table 2. The Gini change was calculated as the difference between the value for the current and the previous year.

Source: Own elaboration.

To assess the economic importance of independent variables included in the analysis, we recalculated our models with the variables after standardization. Figure 5 presents the standardized coefficients from Models 1-4 along with their 95% confidence bands, which allows checking how much the dependent variable changes due to a one-standard deviation change in the independent variable. Our focus is now primarily on factors explaining the Gini levels in the years 2017-2021. It turned out that connectivity (standardized coef. = 0.038) and digital public services (-0.266) were the best predictors of the change in the scale of Gini in 2017-2021 in EU countries (coefficient presented by the black dot in Figure 5), with higher levels of these variables associated with larger increases in Gini. Including fixed-time and country-fixed effects, the integration of digital technology (coefficient presented by the grey square and black triangle in Figure 5) seems to be the best factor in explaining the Gini change.

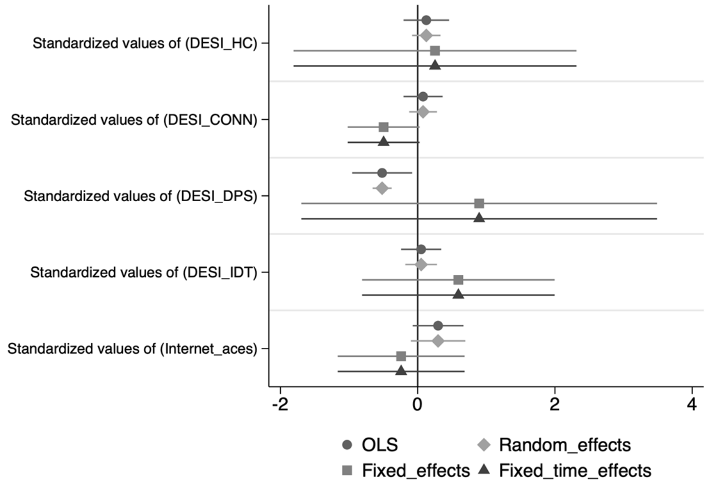


Notes: The figure presents the results of estimation for the variables and specifications used in Models 1-4 in Table 3 after standardization. The legend presents the dependent variables. Lines show 95% confidence intervals. Both dependent and independent variables were standardized. A list of variables is described in Table 1.

Source: Own elaboration.

Figure 5 Regression Results, Standardized Coefficients - Basic Specification, Gini Index in 2017-2021

In the next step, we check if the obtained results are robust to the Gini change to the previous year (Models 5-8 in Table 3). Standardized coefficients for regression are shown in Figure 6. It turned out that human capital, digital public services, and integration of digital technology were the best predictors of the Gini change when country-fixed and fixed-time effects were included.



Notes: The figure presents the results of estimation for the variables and specifications used in Models 5-8 in Table 3 after standardization. The legend presents the dependent variables. Lines show 95%, confidence bands. Both dependent and independent variables were standardized. A list of variables is described in Table 1.

Source: Own elaboration.

Figure 6 Regression Results, Standardized Coefficients - Basic Specification, Gini Index Change to the Previous Year

Our results lead to four main indications. First, the integration of digital technologies is the main factor in reducing income inequalities. Digital technologies enable businesses to gain a competitive advantage, improve their services and products, and expand their markets. The productivity of companies investing in data-driven innovation and data analytics grows by approximately 5% to 10% faster than that of companies not investing (OECD 2015). The EU Digital Decade proposal set out the ambitious targets to be reached by 2030 in this area: more than 90% of European SMEs to reach at least a basic level of digital intensity, 75% of EU companies to use the cloud, AI, and big data and grow scale-ups & finance to double EU Unicorns (European Commission DESI 2022, Integration of digital technology). EU Members States propose a large set of investments generally supporting the digitalization of business, with the largest investments coming from Italy, Spain, Germany, and Greece.

Secondly, in our model, Internet access turned out to be more significantly and negatively linked with income inequalities instead of broadband connectivity. The Digital Decade defines two targets in broadband connectivity for 2030: gigabit coverage for all households and 5G in all populated areas. Despite progress over the last few years, broadband coverage remains uneven between rural and urban areas and remains challenging in the first one. In rural areas, 8.5% of households are not covered by any fixed network, and 32.5% are not served by any NGA technology. However, 4G is also widely available in rural areas (99.6%) (European Commission DESI 2022, Digital infrastructures). In turn, almost 92% of the population (EU27) had basic Internet access in 2021.

The third indication states that digital public services are important in reducing income inequalities. Effective e-government can provide a wide variety of benefits including more efficiency and savings for both governments and businesses. It can also increase transparency and openness. The online availability of public services has been growing steadily over the last decade, accelerated by the COVID-19 pandemic during which digital interaction had to become the norm. The Digital Decade has the target that all key public services for businesses and citizens should be fully online by 2030, and many of EU states are already close to the 100% target. However, progress is still uneven across and within EU countries. Moreover, services for citizens are less likely to be available online when compared to services for businesses, and the availability of more advanced public services that make use of innovative digital technologies (e.g., AI, big data, robotics, etc.) still requires significant investment (European Commission 2022d).

Finally, digital skills turned out to be less important in inequalities reduction in a short-time perspective. While 87% of people (aged 16-74) used the Internet regularly in 2021, only 54% possessed at least basic digital skills (26 percentage points below the target with stark differences among countries)[8]. Some EU countries like the Netherlands and Finland approach the target with 79% of people with at least basic digital skills in 2021. In eight EU countries, the share of individuals with at least basic digital skills is lower than 50%. Romania, Bulgaria, Poland, and Italy rank the lowest. The digital transition is on the rise, but still, in some countries, the workforce does not keep up with the evolving skill demand. Without a firm command of digital skills, there is no way to propel innovation and remain competitive (European Commission 2022).

5. Conclusion

The last few years have highlighted the importance of the data economy. Companies that have embraced digital technologies are better able to cope with the disruptions posed by the pandemic. Europe has converged in digital infrastructure, but more needs to be done to accelerate the commercial use of digital technologies. Within countries, the impacts of coronavirus on short-time work schemes were highly unequal due to their advancement in digitalization and the lockdown policy introduced. Some countries, like Germany, which has a well-established, short-time work scheme and advanced technologies, are substantially less likely to be affected by the crisis. Workers in alternative work arrangements and who can only do a small share of tasks from home are more likely to have lost their jobs and suffered falls in earnings (Adams-Prassl et al. 2020).

We presented strong evidence that even though the immediate labor market impacts of COVID-19 differ considerably across countries, CEE countries suffered more falls in earnings than EU14. It could be the effect of the more likely loss of jobs due to less advancement in digitalization and a small share of tasks that can be done from home. The basic results of our research also show that the scale of inequalities in EU27

[8] The EU aims to equip at least 80% of people with at least basic digital skills and increase the number of ICT specialists to 20 million (around 10% of total employment) with convergence between men and women by 2030.

countries increased more in countries that had larger connectivity measured by access to broadband Internet. Only the integration of digital technology and basic Internet access is crucial for socioeconomic inclusion and, according to our study, related to the larger decrease in the Gini index in 2017-2021.

To generalize the obtained results, it is worth noticing that the problem of income inequality is a very complex phenomenon influenced by a very wide set of various factors. Therefore, the obtained results should be treated with great caution. Moreover, a possible limitation of the analyses carried out with the rapid changes still going on is that the economic impacts of the new challenges such as uncertainty, concerns about the new pandemic waves, and currently the energy crisis could have been underestimated, and may change the path of technological transformation of countries in the future. There is local multiplication of structural change in otherwise unaffected sectors with a further decrease in income. Therefore, there are several avenues for further research. So far, the findings presented in this paper are short-term. Further analysis is to reveal how the development of income distribution after the COVID-19 pandemic is to be differentiated in the long-term and to national specificities such as the existing state of institutional arrangements (e.g., labor policy, social security, development strategy), different varieties in the (inter)national institutions at higher special scales, and the changing sectoral composition (due to current energy crisis). The potential variables of interest are countless: the appropriate infrastructure to support accelerating digitalization, regulations, education, development of digital skills, etc.

The type of work is transitioning from mundane tasks to more imaginative, challenging, and high-level skills jobs. In the future, not only will the expertise required for employment continue to evolve, but the compensation for work will also change, with more individuals working independently under non-standard employment agreements, such as temporary or part-time contracts or self-employment. To address income inequalities arising from these transformations, innovative ideas and policy adjustments will be necessary for several areas, such as competition regulations, innovation systems, knowledge dissemination, digital infrastructure, skill enhancement, retraining programs, social safety nets, and tax policies. Further exploration of these matters is warranted for future research.

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Appendix

Table A1 Regression Results for the Top 10% Income Share

Specification	OLS	Random effects	Fixed effects	Fixed-time - effects
Model # **Dep. variable**	**(1)** **Top10 share**	**(2)** **Top10 share**	**(3)** **Top10 share**	**(4)** **Top10 share**
DESI_HC	-0.287	-0.246	-0.144	-0.182
	(0.209)	(0.276)	(0.315)	(0.337)
DESI_CONN	0.186	0.0699	0.0589	0.0472
	(0.123)	(0.0493)	(0.0505)	(0.0352)
DESI_DPS	0.0716	-0.213	-0.303*	-0.484
	(0.0944)	(0.138)	(0.153)	(0.403)
DESI_IDT	-0.415***	0.158	0.251	0.239
	(0.141)	(0.162)	(0.172)	(0.172)
Internet_access	-0.00138*	3.89e-05	0.000166	5.02e-05
	(0.000736)	(0.000372)	(0.000360)	(0.000300)
GDP_per_capita	3.25e-07**	-1.78e-07	-2.12e-08	
	(1.47e-07)	(2.88e-07)	(4.36e-07)	
Productivity	0.000727***	0.000182	0.000123	
	(0.000114)	(0.000155)	(0.000200)	
Constant	0.406***	0.362***	0.348***	0.384***
	(0.0541)	(0.0344)	(0.0360)	(0.0601)
Country FE			✓	✓
Year FE				✓
Observations	134	134	134	134
R-squared	0.308		0.079	0.089
Number of country		27	27	27

Notes: Robust standard errors are reported in parentheses. Asterisks denote significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. A list of variables is described in Table 2.

Source: Own elaboration.

Table A2 Regression Results for Ratio of Top 10% to Bottom 50% Income Share

Specification	OLS	Random effects	Fixed effects	Fixed-time -effects
Model # **Dep. variable**	**(1)** **Top10 to bottom 50 share**	**(2)** **Top10 to bottom 50 share**	**(3)** **Top10 to bottom 50 share**	**(4)** **Top10 to bottom 50 share**
DESI_HC	-12.67	-11.78	-7.673	-12.79
	(10.07)	(11.93)	(14.72)	(17.19)
DESI_CONN	15.36**	4.876*	4.500	3.720**
	(6.487)	(2.611)	(2.674)	(1.804)
DESI_DPS	1.107	-9.933	-15.13*	-37.25
	(5.796)	(8.465)	(8.504)	(25.52)
DESI_IDT	-22.51***	3.810	9.372	8.880
	(7.224)	(8.093)	(8.247)	(8.224)
Internet_access	-0.0845**	0.00343	0.00993	-0.00444
	(0.0343)	(0.0227)	(0.0212)	(0.0149)
GDP_per_capita	1.20e-05	-2.45e-05	-2.92e-05	
	(7.77e-06)	(1.69e-05)	(2.67e-05)	

Productivity	0.0459***	0.0124	0.0116	
	(0.00781)	(0.00952)	(0.0115)	
Constant	11.90***	9.461***	9.012***	13.34***
	(2.516)	(1.893)	(1.827)	(3.674)
Country FE			✓	✓
Year FE				✓
Observations	134	134	134	134
R-squared	0.405		0.072	0.119
Number of country		27	27	27

Notes: Robust standard errors are reported in parentheses. Asterisks denote significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. A list of variables is described in Table 2.

Source: Own elaboration.