The effect of digitalization on unemployment reduction

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Abstract

Digital transformation and the digitalization of economic activity are ongoing trends profoundly shaping the global economy. Digitalization reflects digital inputs in the production process and new household and government consumption modes, investment possibilities, and financial instruments, increasingly envisaged by digital technologies and tools. This is also impacting the labour markets, on the one hand substituting machines to labour for routinized tasks and thus decreasing the demand for soft skills labour, but on the other hand, increasing the need for new professions revolving around new production and consumption modalities and digital skills. Considering these contrasting effects, it is essential to estimate the overall impact of digitalization on employment. Therefore, this study captures the impact of economic growth and digitalization on unemployment change, evaluating a modified version of Okun's Law on a balanced panel data set for 58 countries between 2013 and 2019. The results from the estimation of a fixed-effect model show the empirical validity of Okun's law for the sampled countries and a significant contribution of digitalization on unemployment reduction.

Keywords: *Digitalization, Digital economy, Unemployment, Panel data, Fixed effect model.*

1. Introduction

Digital transformation is one trend that is currently reshaping the global economy. Without any doubt, digitalization is deeply affecting societies, economies, and the development of business. Digital transformation has also been labeled the "fourth industrial revolution" (World Economic Forum, 2018).

The decline in information technology prices, which started by the mid of the 1990s, paved the way for the increased importance of Information Technologies (IT) and investment as a source of productivity and caused a related surge in economic growth (Jorgenson, 2001).

The digital economy has often been labeled an engine of innovation, competitiveness, and economic growth. This seems to be particularly true for the industrialized countries who have been putting efforts into creating a suitable environment for digitalization, including digital infrastructure and high-quality internet, widespread connectivity, and access to training and support on digitalization and transformation strategies (Kravchenko *et al.*, 2019). Digitalization has also been read as an enabler of more environmentally friendly circular economies, as it increases resource efficiency by reducing waste, boosting product longevity, and minimizing transaction costs (Antikainen *et al*., 2018).

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Still, there is no clear consensus on what is meant with digital transformation and digital economy, which also affects the possibility of measuring and comparing the degree of digitalization of different economies and societies. In general, reviewing existing definitions of the digital economy, they have in common that they all discuss the digital economy in a narrow sense, primarily identifying it with the digital sector, but then discuss the need to capture the pervasiveness of the use of digital technology in economic value creation. The problem becomes then to draw boundaries, as "increasingly the digital economy has become intertwined with the traditional economy making differences between them less clear" (OECD, 2013).

The COVID-19 containment measures have further accelerated digitalization (Dutta and Lanvin, 2020), with more and more businesses integrating digital processes in their operations and more and more customers moving towards online channels (McKinsey, 2021). At the same time, the pandemic provided an occasion to reflect on the existing digital divide and made differences between "network-ready economies" and "laggards" (Dutta and Lanvin, 2020) more apparent.

Digitalization and the related computer-based automation of routinized functions will impact labor demand and affect wage levels (Acemoglu and Restrepo, 2018). Thus, digitalization can have in principle contrasting effects on the labor markets: On the one hand, digitalization and automation can be expected to decrease the demand for low skilled labor force (Acemoglu and Autor, 2011), but on the other hand, it can be expected to increase the need for new skills profiles. Cross-country differences can be reasonably expected. The industrialization level, which goes together with digital readiness, educational profile, and wage levels, may represent a factor affecting the effect of the digital transformation on the labor markets.

Even though the employment effects of digitalization are very present in the political and academic debate, empirical evidence trying to quantify the overall effect of digital transformation at macroeconomic level is still scarce and non-conclusive. At best of our knowledge, this study is the first contribution estimating the overall effects of digitalization on unemployment for a large sample of industrialized and less developed countries. This is done by evaluating a modified version of Okun's law capturing the impact of economic growth and digitalization on unemployment change. Digitalization was estimated by calculating a digitalization index based on the IMD World Digital Competitiveness score by the Institute for Management Development (IMD, 2020). The econometric model is estimated with fixed country effects on a balanced set of panel data from 58 countries from 2013 to 2019.

2. Digitalization and the digital economy

A massive surge in the use of information and digital technology for business can be traced back to the mid of the 1990s, which witnessed a sustained decrease in the prices of IT and IT equipment (Jorgenson, 2001). Since then, digitalization has become more and more of a global trend and an engine for economic growth (Kravchenko *et al.,* 2019). In a narrow sense, digitalization can be defined as "the process of transforming analog material into binary electronic (digital) form, especially for storage and use in a computer" (Pearce-Moses, 2005).

Digitalization is thus converting materials from the analog format that people can easily read to a digital format, readable by machines only (Singh, 2017). On the other hand, the digitalization of business is a broad concept encompassing digital technologies to change a business model and provide new opportunities to generate added value (Gartner, 2020). More specifically, digitization, digitalization, and digital transformation can be identified as the three stages of the digital transformation of business (Verhoef *et al*., 2019).

The impact of digitalization and digital technology goes, however, beyond the firm level and can be discussed at the macroeconomic level, where it is more and more spoken of the digital era (Shepherd, 2004), digital economy, digital society (OECD, 2020), digitalized economy (Bukht and Heeks, 2017), fourth industrial revolution (World Economic Forum, 2018), and information society (Golinski, 2012). The plurality of concepts used to capture the transformation brought about by digital technologies on the (global) economy reflects the difficulty of its definition. A consensual definition of it would also be a prerequisite for its measurement, or, as with the International Monetary Fund (IMF), the "lack of a generally agreed definition of the "Digital Economy" or "digital sector" and the lack of industry and product classifications for internet platforms and associated services are hurdles to measuring the Digital Economy" (IMF, 2018).

To formulate an encompassing and viable definition of the digital economy, the Organization for Economic Cooperation and Development (2020) reviews existing definitions and classifies them into more traditional reports that are focused on aggregate indicators such as value-added or employment contribution of relevant sectors, input-based, that is included in the digital economy all sectors making use of digital inputs, and into flexible definitions, focused on the intensity of use of digital technologies. Based on that, OECD (2020) defines the digital economy as incorporating "all economic activity reliant on, or significantly enhanced by the use of digital inputs, including digital technologies, digital infrastructure, digital services, and data. It refers to all producers and consumers, including government, that are utilizing these digital inputs in their economic activities" (OECD, 2020). Based on this definition, however, different measures of the digital economy can coexist: more precisely, the economic activity from producers of Information and Communication Technology (ICT) goods and information services represents a core measure of the digital economy, which can be expanded to the value-added derived from digital input, but also to the value-added of firms whose activity is significantly enhanced by the use of digital technologies. Such a broad measure of the digital economy, even though legitimate in principle, points to the difficulty of marking the boundaries of the phenomenon.

According to the International Monetary Fund (2018), the digital economy can be narrowly defined as "online platforms, and activities that owe their existence to such platforms, yet, in a broad sense, all activities that use digitized data are part of the digital economy: in modern economies, the entire economy" (IMF, 2018). Therefore, in its attempt to quantify digitalization's value-added, the IMF prefers to rely on the digital sector, which "covers the core activities of digitalization, ICT goods and services, online platforms, and platform-enabled activities such as the sharing economy".

To foster digitalization and boost the digital economy is defined as referring to "a broad range of economic activities that include using digitized information and knowledge as the critical factor of production, modern information networks as a virtual activity space, and the effective use of ICT as a crucial driver of productivity growth and economic structural optimization" (DETF, 2016). Among the considered aspects to be addressed while trying to foster the digital transformation of the economy, the Digital Economy Task Force (DETF) has been considering its impact on the labor market and the need to address the digital divide issue to make digitalization more inclusive. This was done by also considering the "mismatch between the new skills required by the digital economy and the existing skill set of many workers, with this as a particular challenge for developing and least developed countries (DETF, 2020).

Among the challenges involved in measuring the digital economy, which includes all digital-enabled economic activity (Bukht and Heeks, 2017), is that with the steadily increasing importance of digital technologies and input for all sectors of economic activity, the digital economy is blurring with the economy as a whole. Trying to narrow the concept down, Bukht and Heeks (2017) prefer to speak of the "digitalized economy" to refer to the broad picture while delimiting the digital economy to "all extensive applications of digital technologies plus the production of those digital technologies" (Bukht and Heeks, 2017). Digital technologies are finding applications in almost all sectors of economic activities to involve sectors that were traditionally excluded by digital transformation. In this regard, Valls Bedeau *et al.* (2021) presents an interesting discussion of the potential contribution of digital technologies for the sustainability of food systems and agriculture.

The plurality of definitions formulated regarding the digital economy translates into alternative operational purposes and thus indexes and measures. To capture the development of digitalization and enable cross-country comparisons, the availability of time series data and index coverage in countries are essential elements.

The Digital Economy and Society Index (DESI) measures digitalization of economies and societies along the main dimensions of connectivity that is infrastructure development, human capital, citizen use of the internet, integration of digital technology (captured as digitalization of business and online sales channel development), and digital public services. The DESI was developed with specific reference to the countries of the European Union and has been compiled for the EU member states since 2015 (European Commission, 2020).

To quantify propensity to exploit ICT opportunities, the World Economic Forum launched in 2002 and substantially redesigned in 2019 the Networked Readiness Index (NRI). The index currently covers 134 economies and assesses their performance over the four main pillars of Technology, People, Governance, and Impact. Unsurprisingly, according to the NRI, the top 10 performing countries are high-income economies. There is a positive relationship between GDP per capita and NRI score (Dutta and Lanvin, 2020).

The Digitization Index (DiGiX) "assesses the factors, agents' behavior and institutions that enable a country to fully leverage Information and Communication Technologies (ICTs) for increased competitiveness and well-being." (Cámara and Tuesta, 2017). The DiGiX is computed based on principal component analysis so that weights are endogenously determined and have been estimated since 2015 in 100 countries. Its main dimensions are infrastructure, households' adoption, enterprises' adoption, costs, regulation, and contents.

For this study, we have chosen to rely on the IMD World Digital Competitiveness Ranking, which compares the digital competitiveness of 63 countries, rating them with a score between the minimum of 0 and the maximum of 100. The score is calculated based on the three Digital Competitiveness Factors of Knowledge, Technology, and Future Readiness. Each of these factors is composed of 3 sub-factors: talent, training and education, and scientific concentration for knowledge, regulatory framework, capital and technological framework for technology, and adaptive attitudes, business agility, and IT integration for future-readiness. As for other indexes, also according to the IMD Digital Competitiveness Ranking, the top-performing countries are high-income countries. Further, the ranking supports the idea that strong and stable institutions are prerequisites for digital competitiveness and thus key to investment in the sector. This is corroborated by the strong positive correlation between low risk of political instability and IMD Digital Competitiveness Score. The choice to rely on this indicator as a proxy for the digital readiness of the different economies was motivated by its focus on conducive factors for the digital transformation and not only on the infrastructure, as well as by the existence of a complete panel of data for 58 out of the total of 63 considered countries between 2013 and 2020. In addition, the IMD framework (and in particular its sub-component Knowledge) is very accurate in capturing the type of skills available in an economy, with skills being notably at the core of the debate on the employment consequences of technology and digitalization.

3. Digitalization and unemployment

Digitalization calls for drastic alterations in business models (Verhoef *et al.*, 2019), and enterprises worldwide are digitalizing operations in pursuit of aspects that aid the organization to effectively and efficiently operate and achieve a competitive advantage.

This can be obtained through reduced costs and improved operational efficiency, customer understanding and satisfaction, increased employee productivity, increased innovativeness, and positive customer perception. Digitalization of business operations can lead to significant changes in the labor demand. At this moment, contrasting effects can be expected, as digitalization links to the automation of certain routinized and control functions, reducing thus the need for such soft skills professions, while it can increase the demand for labor force with advanced digital skills, as well as the labor demand of new professional figures, made necessary by the new modality of production and sales channels (delivery for online sales channels). In this regard, Fossen and Sorgner (2019) categorize digitalization into destructive and transformative digitalization. Destructive digitalization refers to the automation of specific jobs and tasks that replace labor with machines and can also be defined as computerization or automation (Frey and Osborne, 2017). Transformative digitalization, on the contrary, refers to settings where labor productivity is enhanced by digital technologies and the interaction between workers is facilitated by ICT equipment.

Digitalization has been thus discussed in its capacity to alter equilibria on the labor market (Acemoglu and Autor, 2011; Acemoglu and Restrepo, 2018). Several studies have been documenting and analyzing the effects of digital transformation on the labor market. These research efforts can be read as part of the longstanding tradition investigating the employment effects of technological change and relate to the skill bias of technical change (Tinbergen, 1974, 1975). The concept of skill bias, which has been empirically shown to have accelerated in the 1980s and 1990s (Autor *et al*., 1998), posits that technology adoption reflects into an increase of demand for more skilled workers. More recently, the skill bias is assuming different forms and seems to be more leading to job polarization, that is with a reduced demand for middle-skilled workers vis a vis an increase in the demand for low- and high-skilled workers (Acemoglu and Autor, 2011).

The effects of digitalization will reflect into structural changes in employment (Brynjolfsson and McAfee, 2011) and it can be reasonably expected that forms of employment no longer matching technological development will be replaced by other forms (Eichhorst and Buhlmann, 2015; Rinne and Zimmermann, 2016). It is still not clear, whether the overall trend will be rather towards increased job polarization, upskilling, or job loss (Eurofound, 2015).

It is of utmost importance to understand the overall impact of digitalization on unemployment. Several studies have been trying to provide an answer estimating the automation potential of jobs, focusing on probability of an occupation being automated (e.g. Frey and Osborne, 2013, and Dengler and Matthes, 2015, for the United States; Bonin *et al.*, 2015, for Germany). However, the empirical results based either on micro-surveys or on experts' evaluations differ based on the dataset adopted, on the focus on professions rather than on activities, and on the country of reference.

In regard to the effects of digitalization on the labor markets, the digital divide across countries (Corrocher and Ordanini, 2002) can be expected to impact, too, with pronounced cross-country differences, potentially augmented by expanded offshoring possibilities (Acemoglu and Autor, 2011).

In contributing to this debate, this study adopts an aggregated macroeconomic perspective and aims at quantifying the overall effect of digitalization for a sample of both industrialized and less developed countries.

4. The effect of digitalization on unemployment – Econometric model and estimation results

A variation of Okun's law was estimated to capture the net effect of digitalization on unemployment empirically. Okun's law, proposed and empirically tested in the seminal work by Okun (1962) concerning the United States, relates to an empirical regularity concerning the relationship between actual output growth and the change in unemployment.

Many studies have confirmed the validity of this applicable law for the United States (e.g., Gordon and Clark, 1984; Kaufman, 1988; Knoester, 1986; Prachowny, 1993; Smith, 1975; Weber, 1995; Nektarios, 2019). Moreover, Okun's law has been found to hold also for other countries, even though with significant heterogeneity across economies (Ball *et al*., 2013; Moosa, 1997). Okun's law provides a measure for the elasticity of output growth relevant to the unemployment rate. The fit of Okun's law is typically more pronounced (in the sense that the negative relationship generally is steeper) for advanced countries; in other words, "less sophisticated an economy is the less responsive is the labor force to changes in GDP" (Farole *et al.*, 2017).

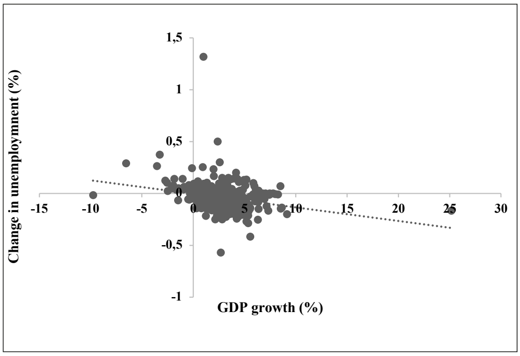
Few notes are due in regard to the choice of the model and its relation to the existing literature on the determinants of unemployment. In general, as due to its stability, the Okun's Law is considered a suitable paradigm to explain unemployment based on macroeconomic data. An alternative paradigm is represented by Philipps Curve, which postulates the existence of a short term negative relationship between inflation and unemployment (Phillips, 1958). There is however a growing body of evidence questioning the validity of Philipps Curve (Elliot, 2015; Pallis, 2006; Dritsaki and Dritsaki, 2012) or, better, pointing to the fact that the relationship between inflation and unemployment could have a different sign depending on labour market institutions and characteristics (Lui, 2009). Besides economic growth and inflation (as respectively postulated by the Okun's Law and by Philipps Curve), labor productivity (Gordon, 1997; Bräuninger and Pannenberg, 2002), population growth, together with variables modeling institutional characteristics (Krugman, 1994) have been discussed in the literature. Also Foreign Direct Investment and foreign debt have been shown to be related to unemployment (Jude and Silaghi, 2015, respectively Nguyen, 2018). There is no conclusive evidence on the determinants of unemployment, in the sense that their significance and effect strongly differ across countries. As a result, most of the studies trying to empirically rationalize unemployment have been focusing on one specific country or on small groups of countries with similar institutional characteristics (Folawewo and Adeboje, 2017).

Okun's law postulates the existence of a negative relationship between the change of unemployment and real economic growth. This can be expressed by the following equation (Knotek, 2007) (Eq. 1), where εt represents the error term and t the period.

$$\Delta U_t = c + \beta_1 GDPgr_t + \varepsilon_t \quad (1)$$

As shown in Figure 1, the data considered for the present study provides evidence of a Downward association between the change of unemployment and economic growth. This reveals that Okun's law applies to the considered countries.

Figure 1 - Okun's law for the sampled data.



To measure the impact of digitalization on unemployment, we added an index obtained normalizing the IMD Digital Competitiveness Score (DIGIT) to Okun's law as a further explanatory variable. Herewith, the model (Eq. 2) to be estimated becomes:

$$\Delta U_{it} = c + \beta_1 GDPgr_{it} + \beta_2 DIGIT_{it} + \varepsilon_{it} \quad (2)$$

The dependent variable is change in unemployment ΔU of country i at time t; the explanatory variables include the natural economic growth GDP gr and the Digital Competitiveness Score DIGIT.

The estimation is based on a balanced panel dataset between 2013 and 2019 for 58 countries covered by the IMD ranking. Even though the IMD ranking includes 63 countries, some countries had to be excluded to have a balanced panel, as, for those countries, not all of the years were covered.

Figure 2 ranks the countries considered according to the normalized IMD Digital Competitiveness Score for 2019. The top-performing country was the United States, followed by Sweden, Switzerland, and Finland.

Even though data for 2020 would have been available, that year was excluded due to the emergency and extraordinary circumstances created by the COVID-19 pandemic. Data for unemployment and GPD growth refer to the World Development Indicators (2019). Table 1 presents some descriptive statistics on the set of variables used for the estimation.

Figure 2 - IMD Digital Competitiveness Ranking for the year 2019.

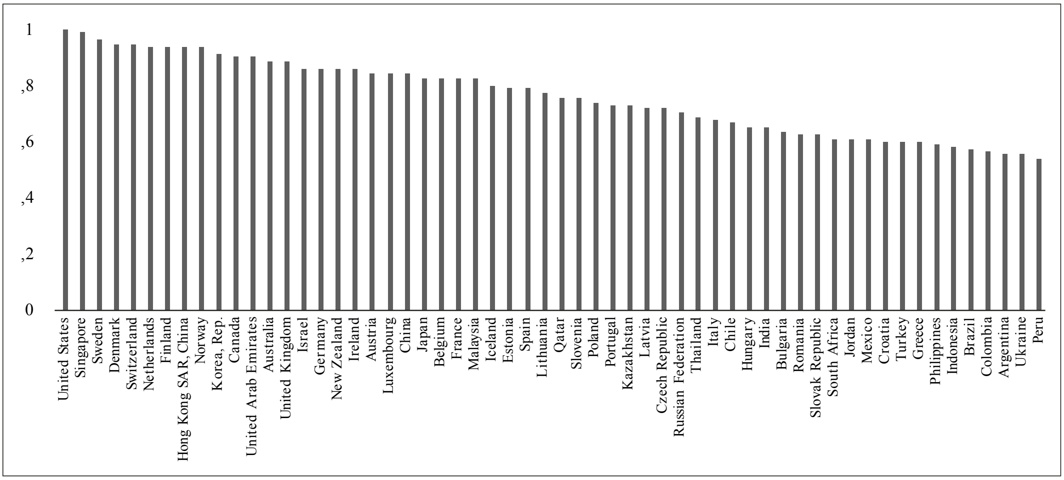


Table 1 - Descriptive statistics.

	Change in unemployment	*GDP growth*	*DIGIT*
Mean	-0.0399	2.7623	0.6931
Median	-0.0517	2.5350	0.7150
Std. Dev.	0.1246	2.4171	0.1819
Minimum	-0.5689	-9.7730	0.3190
Maximum	1.3200	25.1760	1.0000
Count	406	406	406

Table 2 - Correlation Matrix.

	Change in unemployment	*GDP growth*	*DIGIT*
Change in unemployment	1.000		
GDP growth	-0.253 0.000	1.000	
DIGIT	-0.114 0.022	-0.019 0.708	1.000

The correlation matrix for the variables used in the model specification is provided in Table 2. The correlation results indicate a negative relationship between the change in unemployment and GDP growth and digitalization. There is no correlation between GDP growth and digitalization which assures us that including both variables in our model will not introduce multicollinearity and bias the results.[1]

The Unit Root test shows that all variables are stationary. To determine the most appropriate model to estimate equation (2), we compare a pooled regression model, a fixed-effect model (FEM), and a random effect model (REM). Assuming homogeneity in all cross-sections, pooled regression models are appropriate without country-specific effects. This is not the case for our data, so that pooled regressions models cannot be meaningfully used. On the other hand, fixed and random effect models differ in assuming country-specific results: the fixed effect model defines heterogeneity as a time-invariant individual intercept. In contrast, the intercept is modeled as a random outcome variable in the random effect model. Further, the REM relies on the assumption of a standard mean intercept value of the cross-sections and models individual differences in the intercept values of each cross-section via the error term (Greene, 2003; Gujarati and Porter, 2009).

Diagnostic tests (relying on the statistical software STATA and EViews) reveal that the most appropriate analysis model is the fixed ef-

[1] Additionally, we use VIF to detect the severity of multicollinearity. The value of VIF is 2.11 indicating no multicollinearity.

fect model. According to the redundant stationary effect test (with a cross-section F of 2.750, p=0.0000), the null hypothesis can be rejected, implying that the fixed effect model (FEM) is more appropriate than the pooled Ordinary Least Squares (OLS). With a cross-section random of 8.15 (p=0.0170), the null hypothesis of the Hausman Test could be rejected.

The results of the FEM are presented in Table 3.

Overall, all of the estimated coefficients of the fixed effect model (FEM) are highly significant. The F statistics (3.379) value supports the estimated model's overall significance. The Durbin Watson test for autocorrelation indicates (with a value of 2.482) that there is no serial correlation. The estimation confirms the existing relationship between change in unemployment and GDP growth and provides evidence for a negative effect of digitalization on the change in unemployment. This significant result corroborates the nexus between digitalization and labor market dynamics and thus helps to contextualize better the role of digitalization in creating job opportunities. The overall result shows that improving digital readiness is associated with an increase in employment levels or decreased change in unemployment as with the estimated model. This can be generally read as a call towards investing in creating suitable conditions for digitalization and reducing the digital divide. This can be particularly challenging for less developed countries, which are disadvantaged in terms of digital infrastructure, penetration of digital technologies, and state of the art education to equip people with digital skills. As also captured by the IMD score and its sub-components, the digital transition requires appropriate skills and knowledge, as well as a suitable regulatory framework, technology adoption, and IT readiness. Limited financial and institutional capabilities of less developed countries may delay the digital transformation. However, the digital divide also exists among different social groups within the same economy, with different levels of digital literacy and asymmetric access to digital technologies.

At this moment, every country needs to envision strategies to promote widespread re- and up-skilling (Dutta and Lanvin, 2020).

Table 3 - Estimation results.

VARIABLES	*(1)* *Change in unemployment*
DIGIT	-0.2732** (-3.50)
GDP growth	-0.0190** (-2.82)
Constant	0.2018** (3.54)
Observations	406
R-squared	0.3656
within Adjusted R-squared	0.113
F test	0.000161
Robust t-statistics in parentheses	
*** p<0.01, ** p<0.05, * p<0.1*	
Estimations were done using STATA and Eviews	

5. Conclusions

Digitalization and the transformation towards the digital economy are changing the way production, consumption, and work are organized. While these trends have been ongoing since the 1990s, they have witnessed an acceleration over the last decade and a decisive push during the time of the COVID-19 health emergency.

Digital transformation has been discussed as a source of competitive advantage and an engine of economic growth. However, digital transformation is disruptive of old equilibria and may imply profound changes in the global economic system. Its impact on the labor markets is currently widely discussed without conclusive evidence, so far. The overall result of digitalization in terms of employment creation or instead unemployment is, in principle, uncertain. While, on the one hand, the automation of routinized tasks reduces the demand for unskilled labor, digitalization is creating the demand for new professions revolving around new modes of production and consumption. It is essential for governments worldwide to understand the digital revolution's overall impact on employment, boost desirable effects, and increase preparedness to mitigate eventual negative implications and support the social groups who may be left behind. Therefore, the present paper captures the overall impact of digitalization on unemployment. This relied on a modified version of Okun's law, regressing unemployment reduction against economic growth and a normalized coefficient for digitalization. The estimation was conducted for a balanced panel data set from 58 countries between 2013 and 2019.

For the sake of the present analysis, the simple but stable framework of the Okun's Law provides a suitable model to test for the effects of digitalization on a sample of countries with different characteristics, different levels of development, different labor productivity, and different subsets of skills. On the other hand, some institutional characteristics are captured in our model by the digitalization coefficient used, which includes aspects related to skills, regulatory framework, technology, and business agility.

The results corroborate the significance and validity of the model, estimated via a fixed-effect model, and reveal a significant and negative effect of digitalization on unemployment change. This means that an increase in the digitalization readiness of countries leads to a substantial reduction in unemployment.

Based on this evidence, we conclude that digitalization can be a chance for employment creation worldwide. We recommend that governments and the international community activate strategies to reduce the digital divide across and within countries to make the digital transformation a source of inclusive development. At country level, investments in education, digital literacy, up-, and re-skilling are mostly needed, to prepare the labor force to the digital skills requested by the labor markets. International support will be also needed to encourage and enable less developed countries to improve their digital infrastructure and the penetration of digital technologies.

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