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Article

EU Diversity in Terms of Digitalization on the Labor Market in the Post-COVID-19 Context

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Abstract: Digital technologies are being integrated into everyday life worldwide, constantly transforming our society and labor markets. The EU requires digitally smart people in the labor market and has promoted this through the Digital Agenda. In this context, our paper aims to investigate the diversity of the EU member states in terms of the digitalization of the labor market in the post-pandemic context. Using a multidimensional perspective, we considered indicators reflecting not only labor market specificities but also the degree of digitalization and the impact of the COVID-19 pandemic. First, the strength of the association between digitalization and the labor market indicators was quantified through a Pearson test, while the cluster analysis highlighted some patterns for the high-tech EU economies compared to the medium- and low-tech EU economies. Among the high-tech economies cluster, Finland stands out as the frontrunner in the EU's digital transformation, with the most digitally skilled workers. At the opposite pole are the South-Eastern countries, which have the most to do to recover and still lack an effective digital policy framework to support youth workers' access to digital training. The practical implications of our study consist mostly of providing decision-makers with directions on issues to tackle when implementing EU digital policies.

Keywords: digitalization; youth employment; labor cost; labor productivity; cluster analysis; COVID-19 impact

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1. Introduction

Digitalization is permanently shaping our society as economies worldwide are going through a transformative process that requires digital technology integration into everyday life. Being accelerated by novel technologies, digitalization has a notable social and economic impact, by changing the digital job skills requirements of the labor market and by challenging the youngest generations and their process of job finding.

Nowadays, the European Union (EU) requires digitally smart people in the labor market and has promoted this through a bi-dimensional EU policy framework. On the one hand, there is the Digital Agenda for Europe (European Commission 2010), the Digital Single Market (DSM) for Europe (European Commission 2015), and a Europe fit for the digital age (European Commission 2020), referring to digital skills development among all citizens, while on the other hand, there is the EU Youth Strategy 2019–2027 (European Union 2018; European Commission 2018a, 2018b) focusing on promoting digital tools among youth.

More precisely, the Digital Agenda for Europe (European Commission 2010) promotes the digitalization of Europe from a multidimensional perspective. In terms of job creation and skills development, it stimulates the growth of startups and small- and medium-sized enterprises (SMEs) in the technology sector, leading to new job opportunities in the digital sector and digital training. In terms of competitiveness, it promotes both the development of e-government services to make public administration more efficient and accessible and the digitalization of industries to become more technology-driven and data-centric, with improved broadband infrastructure and connectivity across Europe.

In addition, the DSM for EU (European Commission 2015) implies the removal of barriers to cross-border e-commerce and digital services, which could boost online businesses and the digital economy and, in turn, lead to increased demand for digitally skilled jobs. Moreover, A Europe Fit for the Digital Age (European Commission 2020) supports digital transformation and innovation, as well as cybersecurity and green digital transition, and promotes investments in digital education and the adoption of technologies like artificial intelligence (AI), blockchain, and high-performance computing, which can lead to increased productivity and competitiveness across industries. All these initiatives have created opportunities for businesses to thrive in the digital economy while promoting the development of digital skills, job creation, and economic growth in the digital sector.

Finally, the EU Youth Strategy 2019–2027 (European Union 2018; European Commission 2018a, 2018b) primarily focuses on youth-related issues but indirectly contributes to the EU's efforts to leverage digital technologies for economic growth and job creation by recognizing the importance of digital skills and education, digital entrepreneurship and startups, as well as digital inclusion.

Although digital social inclusion is aimed at ensuring access to information and communications technology (ICT) for all individuals, the Digital Agenda is still not yet addressed adequately. Access to ICT is currently evaluated through the following elements: (1) affordability and robustness of broadband internet services; (2) accessibility to digital training; (3) internet-enabled devices; (4) qualitative technical support; (5) online content and applications to enable self-sufficiency. Even though ICT could enhance young human capital (McLoughlin 2018), there are still structural and institutional barriers to the use and access to digital technologies (Serban et al. 2020).

In order to overcome the digital gap and inequalities among youth work, the conclusions on digital youth work (Council of the European Union 2019) aim to prioritize youth workers' access to training and education in the field.

Regarding the impact of digitalization on the labor market, the topic is multi-faced. On the one hand, digitalization is expected to create new job opportunities, especially in areas like e-commerce, information technology, and social media, while on the other hand, it could lead to the displacement of specific jobs in traditional industries like retail and manufacturing. Moreover, the COVID-19 pandemic has further extended the challenges young workers are facing in the labor market, emphasizing the need for new investments in education and training programs to support young workers in developing the digital skills required for future jobs.

Studying the overall picture of the digitalization process in the EU labor market becomes, therefore, a notable challenge that we are willing to accept to fill this gap in the field.

Thus, our paper aims to investigate the diversity of the EU member states in terms of digitalization of the labor market and to find the main patterns between the EU countries in the post-pandemic context. Since the labor market is constantly influenced by so many external factors in the EU context, our research demanded a more complex approach to cover as many insights at the country level as possible. Therefore, we gathered a potential list of indicators at the EU level for the year 2022 from a multidimensional perspective in order to reflect not only the labor market specificities of each EU country but also the degree of digitalization and the COVID-19 pandemic impact upon each country. Among the labor market indicators, we considered relevant factors: youth employment, labor cost, and labor productivity. A Pearson correlation test first brought some initial hints on the strength of the association between digitalization and labor market indicators. The analysis was then followed by a cluster analysis, which highlighted some patterns for the high-tech EU economies compared to the medium and low-tech EU economies.

The structure of the paper is the following. A brief literature review of the field is presented in Section 2, while Section 3 outlines the data collected for our analysis. The methodology applied in this study is presented in Section 4, while the results and the discussion of the implications of our findings are tackled in Section 5. Finally, the paper concludes in the last section, where the main findings of our research are further highlighted.

2. Literature Review

The digitalization phenomenon and its potential impact on the labor market have recently been a topic of intense concern, especially since the Council of the European Union (2019) emphasized the need for labor market digitalization and thus prioritized youth workers' access to training and education in the field. Today, the worldwide process of socio-economic digitalization is expected to bring new opportunities to address the youth unemployment issue. In this context, the measurement of digitalization becomes extremely important, especially since there is no general meaning and approach to measuring digitalization in the current literature review (Basol et al. 2023). Identifying the most appropriate measurement tool is thus a rather challenging task. Among the most popular options for measuring digitalization, we identified the following:

(1) The Digital Adoption Index (DAI) proposed by the World Bank (2016),
(2) The Digitalization Index (DiGiX) proposed by BBVA Research (2017),
(3) Enabling Digitalization Index (EDI) proposed by Euler Hermes (Economic Research 2018),
(4) The World Digital Competitiveness (WDC) developed by IMD World Competitiveness Center (2022),
(5) The Digital Economy and Society Index (DESI) was developed by the European Commission (DESI 2022a, 2022b).

There are several differences between these indexes based on their main measurement purpose. For instance, DAI is a composite index that studies the digital adoption of a country across three dimensions, namely people, business sectors, and government. EDI evaluates a country's capacity for digital dividends, while DiGiX focuses on agents' behavior and institutions that empower a nation to effectively utilize information and communication technologies (ICTs) for enhanced competitiveness and overall well-being. WDC quantifies 63 economies' degree of readiness to adopt and use digital technologies to trigger economic transformation in business, government, and wider society. Lastly, DESI is a composite index designed to assess the digital competitiveness of European Union nations and oversee their overall digital achievements. A critical comparison of these main digitalization indexes' strengths and weaknesses is summarized in Table 1.

Table 1. Strengths and weaknesses of the main digitalization indexes.

Index	Strengths	Weaknesses
DAI	• Allows organizations to assess and track their progress in adopting digital technologies and set benchmarks/goals for digital transformation.	• Does not account for contextual differences (organization's industry, size, location or culture). • Recent data for DAI is unavailable.
DiGiX	• Assesses the level of digitalization in a region and monitors progress or issues in digitalization strategies implementation. • Complex structure adding up 21 individual indicators through 6 dimensions: infrastructure, enterprises' adoption, households' adoption, costs, regulation and contents.	• Has limitations in capturing the full complexity of digital transformation and its impact on various aspects of society and economy. • Recent data for DiGiX is unavailable.
EDI	• It is a key tool in measuring the impact of digitalization on business and society through five dimensions: connectivity, regulation, knowledge, size and infrastructure.	• It does not fully capture a holistic approach to measuring digitization. • Recent data for EDI is unavailable.

Table 1. *Cont.*

Index	Strengths	Weaknesses
WDC	• Provides a global benchmark for assessing countries' digital competitiveness, by considering multiple dimensions like knowledge and technology factors, the regulatory environment, and the readiness of businesses and governments to adopt digital technologies. • It is updated annually.	• Does not properly account for contextual differences between countries, regions, or industries, potentially oversimplifying complex digital ecosystems.
DESI	• Provides the most comprehensive assessment of digitalization, by considering connectivity, digital skills, internet usage, digital technology integration and digital public services. • Provides policy insights and recommendations. • It is updated annually.	• Even though it brings a holistic view of a country's digital progress, it may not fully capture emerging technologies.

Source: authors' own contribution.

We conclude that WDC and DESI are the most comprehensive and annually updated indexes. For our research purpose, however, we consider the DESI index to be the most appropriate, as it offers the most holistic approach to measuring digitalization. DESI's primary goal is to pinpoint the specific areas in each European Union country that require investment in the context of economic and social digitalization.

The interest in the digital area and the labor market can be captured by the multitude of studies on the link between the two. In addition to conventional research methods, modern techniques are applied to highlight the most important characteristics of the field. For instance, the systematic literature review (SLR) approach, which analyses previous academic papers that study the same issue, is becoming more popular in the new research. This approach was used to demonstrate how Big Data analyses have the potential to improve the comprehension of the labor market (Turulja et al. 2023). In order to increase the effectiveness of the labor market, it is crucial to use data to its full potential. However, the analysis of the data leads to the conclusion that while Big Data is able to become more and more noticeable in the labor market, the articles in this area are not yet sufficiently consistent.

Digitalization through automation, artificial intelligence, and robotics has profound consequences on the labor market, as it can increase the production of goods and services and enhance labor productivity (Tegmark 2017). These new technologies open up fresh employment prospects across various industries and emerging markets (OECD 2016). Kee et al. (2023) and Pirzada (2013) argue that communication and digital skills lead to higher employability, while Picatoste et al. (2018) state that computer skills can boost youth employment. Nevertheless, digitalization can also carry the risk of technological unemployment and decreased wages for some vulnerable groups, especially those with low income and no college degree (Pirosca et al. 2021; Vasilescu et al. 2020).

Regarding the overall impact of digitalization on the labor market, the existing body of literature in this field reveals a lack of consensus. For instance, studies conducted by Atkinson and Wu (2017), Dengler and Matthes (2018), and Acemoglu and Restrepo (2018) argue that, even as routine tasks become automated, it is still feasible to maintain a sustainable job market by generating enough new job opportunities. Additionally, the findings of Schlogl and Sumner (2018) suggest that in developing countries, over 60% of jobs could be vulnerable to automation. Therefore, understanding the relationship between digitalization, job displacement, and employment is crucial, particularly given the positive correlation between digitalization and economic development levels (World Economic Forum 2020).

Future workforce requirements in digital sectors may be predicted by using large-scale data sets that gather information about skill requirements and job descriptions (David et al. 2023). This approach offers more accurate and thorough labor market estimations by taking into consideration the interactions and interdependencies between skills and job openings.

The presence of unexpected events and processes that may be particular to specific periods of time contributes to the labor market's complexity. "Churning" is a term used to describe a process that is becoming increasingly common in the labor market when people regularly switch jobs or go back and forth between being employed and unemployed (Kaderabkova and Malecek 2015). Programs that promote labor-market mobility are becoming increasingly essential since they expand educational options and address the demands of the targeted demographics: young people and those with a higher degree of education.

The relationship between education, the digital environment, and the labor market under the digital revolution has also been a subject of concern in the literature. Titan et al. (2014) discuss the EU's attempts to decrease labor market disparities for those with advanced digital capabilities. Using data from the Eurostat and World Bank, the study compares the population's level of digital skills and their impact on the labor market. Data analytics, digital marketing, cyber security, coding, and artificial intelligence are skills that have been shown to be more important in the employment market environment. The study also emphasizes the importance of digital education to prepare people for the new labor market requirements. Finally, Titan et al. (2014) point out the fact that digitization, along with all the associated processes, such as educating youth in primary school on labor market innovations, can be referred to as the key to keeping the EU on the same level with the United States of America and Japan in terms of economic development. The EU can effectively handle the demands of the digital era by concentrating on these issues, encouraging the workforce to prosper in an increasingly digital and competitive global environment.

In a recent study, Herman (2020) explores the impact of the information and communication technology industry on the labor market while considering the case of Romania, which is currently the least digitalized EU country in terms of the DESI index. It focuses on the expansion and development of the ICT sector, as well as that sector's role in producing employment opportunities and economic progress. The impact of this industry is assessed with the goal of developing labor market policies that benefit employees, organizations, and the overall economic system. The comparison analysis performed using the appropriate BI tools within the EU shows that there are significant differences between Romania and the average of the European Union in terms of the contribution of the ICT sector to employment as measured by the DESI index. Herman (2020) discovers a significant correlation between labor productivity at the level of EU states and the DESI index, which assesses the degree of digitalization. It highlights the significance of putting plans into action to maximize the ICT sector's potential to increase job opportunities and preserve Romania's capacity to adapt to the environment developed within the EU framework. Romania does not hold a favorable position in the circumstances under discussion.

Some previous studies also used cluster analysis to understand digital transformation in EU countries and to gain valuable insights and lessons to drive digital transformation in the EU. For instance, Pinto et al. (2023) emphasize the importance of broadband infrastructure to boost innovation performances, as well as to prioritize initiatives that support digital skills development and ensure comprehensive digital empowerment and wider internet access. In another study, Pirosca et al. (2021) explore the effects of digital skills and internet usage on salaries and wages in EU member states, highlighting the necessity to increase digital proficiency for a more effective and flexible labor market.

As compared to previous studies analyzing the digitalization efforts of the EU countries using similar cluster analysis methodology, our paper has the benefit of providing a more holistic approach in terms of factors considered to trigger recent challenges to the labor market, along with a selection of the most relevant labor market indicators (youth employment, labor cost, and labor productivity) for the EU member states. More precisely, we consider a multidimensional perspective to reflect not only the labor market specificities of each country but also the degree of digitalization and the COVID-19 pandemic impact upon each EU country.

The global COVID-19 pandemic unleashed a series of challenges worldwide, such as healthcare system breakdown, extensive job losses, and higher poverty rates. The most severely hit groups were households reliant on daily earnings and self-employed individuals in low- and middle-income nations (Kamran et al. 2022). Moreover, the World Economic Forum (2020) summarized a set of key points when studying the impact of the COVID-19 pandemic on the future of employment. Firstly, it draws attention to the fast and ongoing adoption of technology, with Big Data, cloud computing, and e-commerce gaining more strategic importance. This is particularly notable in areas where face-to-face meetings were traditionally the norm. Secondly, it pinpoints the disruptions driven not only by the trend of automation replacing traditional jobs but also enhanced by the COVID-19 recession. It also projects that by 2025, job destruction will outplace job creation (an estimated job destruction rate of 6.4% compared to a job creation rate of 5.7%). Lastly, it warns about a potential significant shortage of skilled jobs in the future labor market.

In order to control the spreading of the pandemic, extensive actions were implemented, among which a very notable shift consisted of the transition to remote work. Thus, businesses, particularly small and emerging enterprises, face the urgent pressure to adapt rapidly to online services or to online businesses in order to survive (Scheidgen et al. 2021; Shaikh et al. 2020). Because the pandemic also brought with it the increased adaptation of the population to digitalization norms, employment became much more flexible (Cao 2021). The unpredictable character of events of this type can strongly influence both the labor market and the economy.

All these topics are essential for understanding the labor market and its complexities. These themes investigate many characteristics and variables that impact labor market dynamics, such as the necessity of Business Intelligence, continual learning at the organizational level, and the existence of innovations. When taken as a whole, these publications present fresh, pertinent viewpoints on the labor market's changing nature, illustrate the need for adaptability and flexibility in a dynamic environment, and reinforce the necessity for a strategic response to any potential market challenges.

3. Data Description

The paper intends to investigate EU diversity in the digitalization on the labor market and find the main patterns between EU countries in the post-pandemic context. However, since the labor market is constantly influenced by so many external factors in the EU context considering the post-pandemic crisis, our research demanded a more complex approach to cover as many insights at the country level as possible.

Thus, we gathered a potential list of indicators at the EU level for the year 2022 from a multidimensional perspective to reflect not only the labor market specificities of each EU country but also the degree of digitalization and the impact of the COVID-19 pandemic upon each country.

From the labor market perspective, we considered indicators reflecting not only the youth employment rate but also labor cost and nominal labor productivity, computed as real GDP per total number of hours worked. The data source for these indicators was the Eurostat database.

In terms of digitalization, we opted for the DESI index as a measurement of digitalization, not only due to data availability on the Digital Agenda database but also because it quantifies digitalization in both social and economic dimensions. Additionally, DESI evaluates the degree of digitalization of the EU countries, using nearly 30 distinct indicators grouped under the following four general sub-dimensions: Human Capital, Connectivity, Integration of Digital Technology, and Digital Public Services.

Regarding data collection, another challenging aspect of our research consisted in choosing the right indicator to reflect the COVID-19 pandemic effect on each EU economy. Several potential indicators were initially considered in the analysis, among which were the total number of COVID-19 cases registered since the year 2022, total deaths caused by COVID-19 since 2022, and several composite indexes, such as those computed by Thomas et al. (2021) regarding the Oxford COVID-19 Government Response Tracker. Based on its database and combinations of aggregated indicators, there were four types of indexes publicly available: (1) the Containment and Health Index, (2) the Economic Support Index, (3) the Stringency Index, as well as (4) the Overall Government Response Index. Those indexes allowed quantifying both the economic efforts and the government containment and health measures to respond to the pandemic.

After a preliminary analytical phase, we concluded that despite the advantages the Oxford COVID-19 Government Response Tracker could have through its multidimensional composition, it would not serve our research purpose well. In our attempt to quantify the pandemic's impact on youth employment, such a composite index could not properly reflect the direction of the impact since such an index mostly quantifies the governmental responses to the pandemic and not the pandemic's direct impact upon the EU economies and their labor markets, as intended by us. A better solution to quantify such impact could be the composite COVID index composed by Popescu et al. (2023) using Principal Component Analysis, which also considered the pandemic's pressure on health systems and some general health system indicators. But, since the composed index was computed only for the year 2020, it will not serve our research purpose either.

So, for multicollinearity reasons, we chose only the number of total deaths caused by the COVID-19 pandemic to reflect the impact of the pandemic upon the EU countries and dropped the indicator reflecting the total number of COVID-19 cases. However, following the Popescu et al. (2023) approach, we computed a relative indicator as the ratio between the total number of confirmed deaths due to COVID-19 and the total population registered in each EU country in 2022 to ensure a better and more accurate comparison between the EU countries. The data were collected from the Our World in Data database.

In order to investigate the diversity of the EU member states in terms of digitalization of the labor market and to find the main patterns between the EU countries in the post-pandemic context, our research journey consisted of performing cluster analysis.

The final list of indicators considered in the analysis is summarized in Table 2, where the data set is separated into the three considered groups: (1) labor market indicators, (2) assessment of the pandemic's impact through the ratio of confirmed deaths to total population for each country and (3) the four dimensions of the DESI composite index. The complete data set is presented in Appendix A.

Table 2. Main indicators considered in the cluster analysis.

Indicator	Abbreviation	Definition	Data Source
Labour cost	L1	Total wages and salaries of industry, construction and services (except public administration, defence, compulsory social security) expressed in EUR.	(Eurostat [Dataset] 2022)
Nominal labour productivity	L2	The real GDP per unit of labour input (measured by total number of hours worked). The data is expressed as percentage of EU27 total (based on million purchasing power standards), current prices.	(Eurostat [Dataset] 2022)
Youth employment	L3	The percentage of employed persons (from 15 to 24 years) in relation to the total population.	(Eurostat [Dataset] 2022)
COVID-19 deaths	C1	Total number of confirmed deaths due to COVID-19 relative to total population in 2022	(Our World in Data [Dataset] 2022)
DESI Digital Public Services	D1	The demand and supply for e-government as well as open data policies	(DESI 2022a)
DESI Integration Digital Tech	D2	Consisting of three sub-dimensions: digital intensity, take-up of selected technologies by enterprises and e-commerce	(DESI 2022a)
DESI Connectivity	D3	Both fixed and mobile broadband are considered with indicators measuring retail prices, the demand and the supply	(DESI 2022a)
DESI Human Capital	D4	It evaluates both internet user skills of citizens and advanced skills of specialists	(DESI 2022a)

Source: authors' own selection of data.

However, prior to the grouping analysis, the data were examined both individually and in relation to one another to check the EU's overall economic situation.

In terms of labor market factors, in 2022, the EU's youth employment variable reported an average of 50%, with Greece having the lowest rate of youth employment (33%), followed by Italy (34%) and Romania with 37%. At the opposite pole stands the Netherlands, with a level of 79% of youth employment. The labor cost suggests an extreme difference between the value recorded by Romania (9 EUR) and the EU average (20.04 EUR), being situated at a very short distance from the last place country, Bulgaria (7.10 EUR). In terms of productivity, the overall picture is somehow better because there is not a significant gap between Romania's value (80.8%) and the average for the EU (99.3%).

A common aspect in the case of these three labor market indicators is that the countries with the lowest values are Greece, Bulgaria, Slovakia, Croatia, and Romania, indicating a possible country cluster.

Regarding the pandemic impact, the top three countries most affected by COVID-19 in terms of deaths relative to total population are Bulgaria (0.56%), Hungary (0.49%), and Croatia (0.44%). Figure 1 shows how the South-Eastern region was the most impacted, while in the Western part, the Netherlands stands at the opposite pole with a death rate from COVID-19 of just 0.13%.

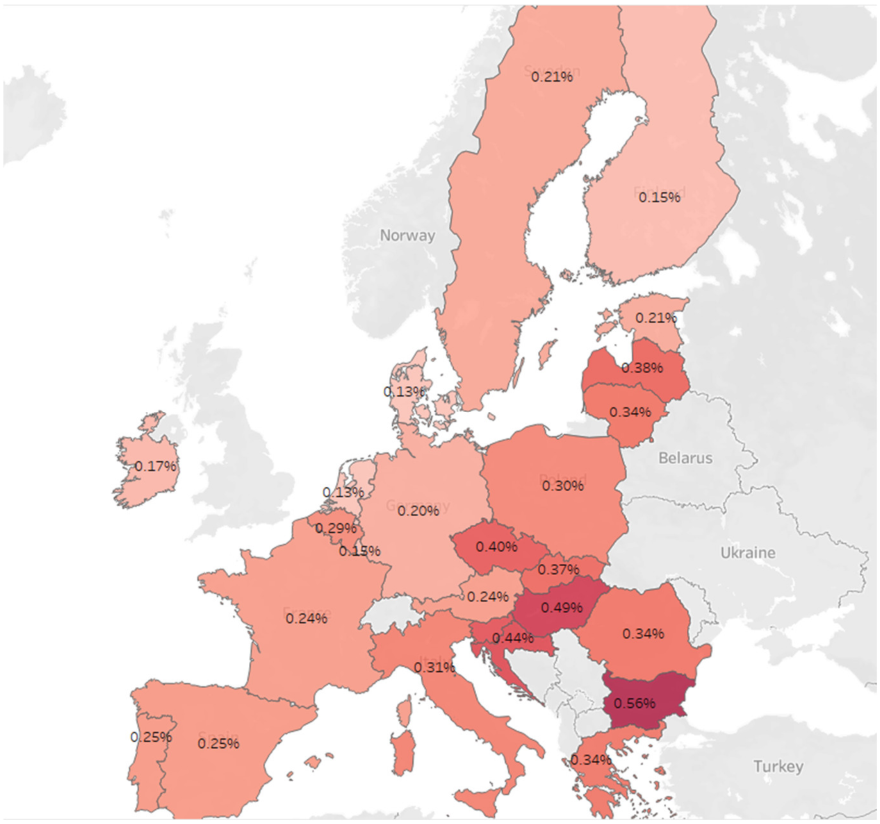

Figure 1. The death rate from COVID-19 in the EU in 2022. Source: authors' own computation.

From the DESI index perspective, the description of the data can be facilitated by breaking it down into its four dimensions (human capital, connectivity, integration of digital technology, and digital public services). Except for connection, Romania is ranked last in the hierarchy of each dimension. Therefore, the level of Internet coverage through the various current methods reflects the country's potential for digital development. Overall, Romania (0.31) ranks last, after Bulgaria (0.38) and Greece (0.39), while the top states, however, take the lead with values between 0.68 (Netherlands) and 0.70 (Finland).

The pattern highlighted in the case of labor market variables is also visible in the case of the four digital dimensions (see Figure 2). Romania and Bulgaria report the same value for human capital (0.08) and integration of digital technology (0.04), both belonging to the lowest top values. Altogether, the above-stated countries tend to be grouped together similarly.

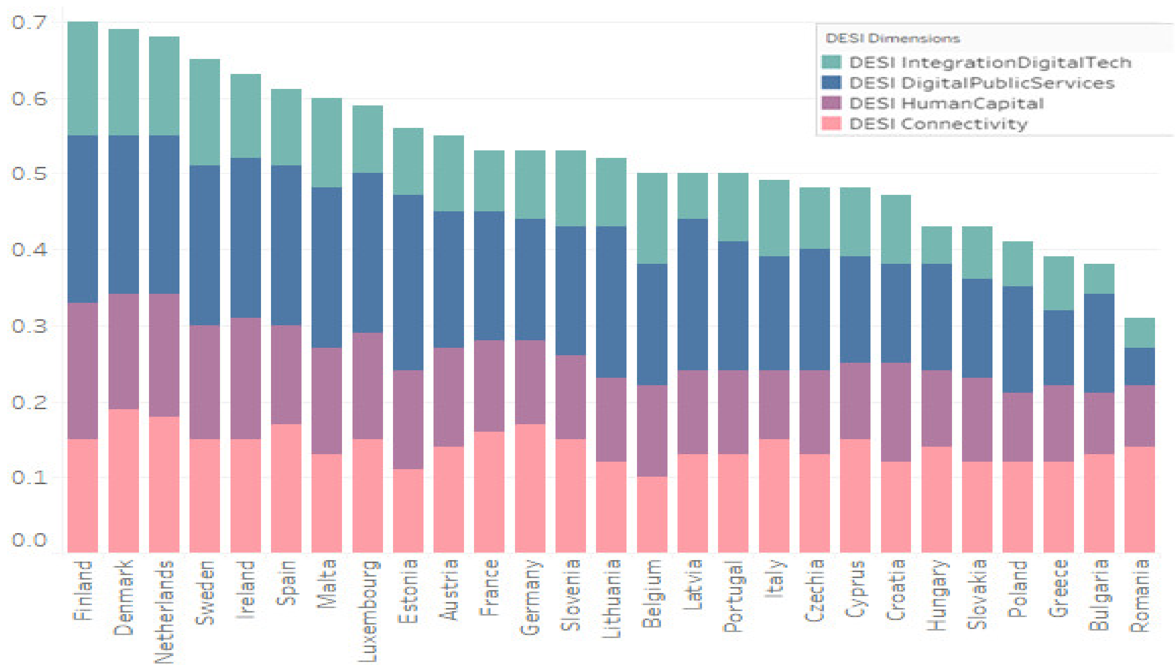

Figure 2. The DESI index in the EU in 2022. Source: authors' own computation.

4. Methodology

A cluster analysis was next performed to investigate the diversity of the EU member states in terms of digitalization of the labor market and to find the main patterns between the EU countries in the post-pandemic context.

The grouping process of the member states consists of a series of steps found in the methodology presented in Stancu (2022) as follows:

Step 1. Development of a data set based on the analysis's objective.

The goal of this cluster analysis is to investigate how EU countries are classified according to the labor market from the perspective of young people, how the COVID-19 pandemic might affect a country's economy, and their level of digitalization in the year 2022. In order to capture the impact of the previously listed categories for the 27 EU member nations, we have prepared a data collection consisting of 8 indicators from official sources, including the Our World in Data statistics, the Digital Agenda Database, and the Eurostat Database (see Table 2).

Step 2. Data preparation and standardization

This stage consists of verifying that some data set rules are followed. After selecting adequate indicators, the missing values must be approximated or removed so that the analysis's accuracy is not compromised. Furthermore, given that the indicators are expressed in different units of measurement, data standardization is required. In this case, it was unnecessary to eliminate or estimate certain missing values, and the data were scaled using the min–max method.

It is preferred to determine the similarity measure between the observations at this step in order to see how the groups might be accomplished. This time, an Euclidean metric is being applied (see Figure 3).

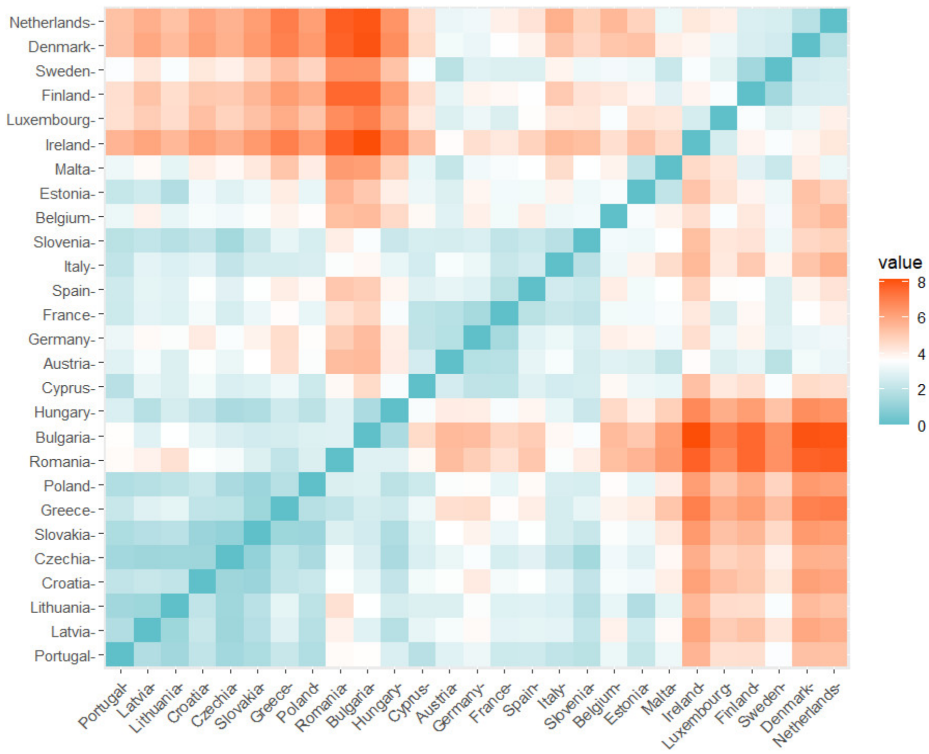

Figure 3. The similarity matrix using R. Source: authors' own computation.

As a result, the blue patches depict the closest associations in terms of similarities between countries. Groupings such as the Netherlands, Denmark, Sweden, and Finland, or Romania, Greece, Slovakia, Poland, and Czechia, can be intuited in this manner.

Step 3. Cluster Analysis

Before applying the analysis, it is necessary to establish the grouping method. The average, single, complete, and Ward techniques are the five fundamental methods used to calculate the distance between clusters and to form the clusters. As a result, the agglomeration coefficient for each approach was computed, and the ward method emerged as the most appropriate.

The Ward method, also known as the minimum variance method, aims to minimize information loss by minimizing the sum of the squared deviations of each variable in the cluster from the mean, i.e., minimizing the total variation in the deviations within the cluster, so that the pair of clusters with the shortest distance between them is the next one at each step.

There are many approaches for determining the optimal number of clusters. For increased accuracy, we examined two approaches whose findings aligned with this example (see Figure 4). Three clusters were shown to be the optimum number through the elbow approach, which looks for a curve in the graphical representation of intra-cluster distances given a set of k clusters.

The "NbClust" package In R offers many techniques for determining the ideal number of clusters, and the NbClust() function calculates the average number of clusters identified by these techniques.

Step 4. Interpretation of the resulting clusters

The interpretation of the three generated groups is performed using centroids, which reflect the average of each variable within the clusters.

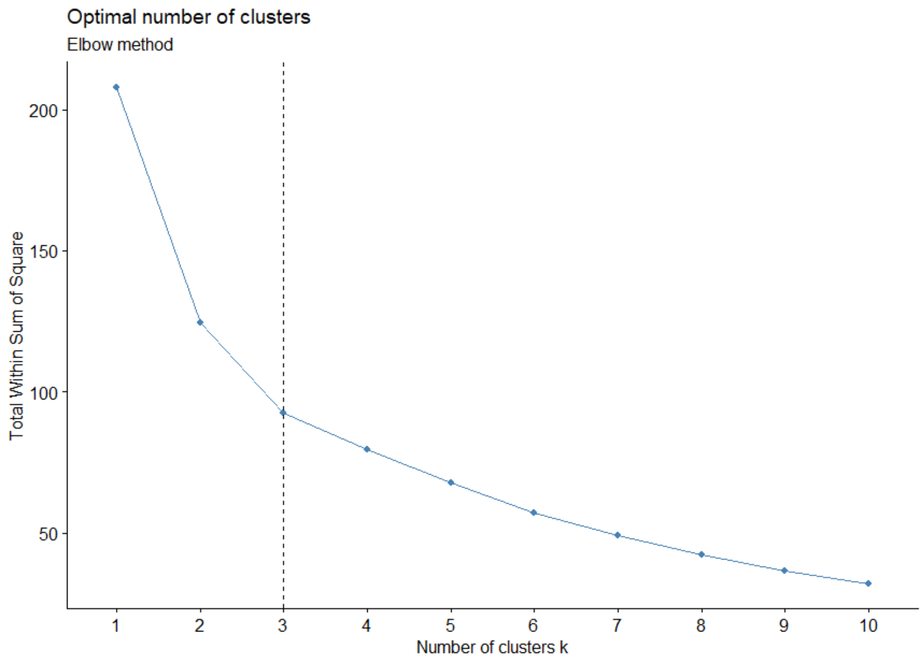

Figure 4. The optimal number of clusters using R. Source: authors' own computation.

5. Results and Discussions

In order to investigate how significant digitalization is correlated with the selected labor market indicators in the EU countries in the post-pandemic era, we initially applied a Pearson two-tailed correlation test. The test was conducted between each of the four main dimensions of the DESI index and the labor market indicators considered in the analysis. The results are summarized in Table 3 and indicate a positive and statistically significant correlation between DESI's four dimensions and the labor market performances of the EU countries.

Table 3. The Pearson correlation test.

Pearson Correlation	Youth Employment	Nominal Labor Productivity per Person	Labor Cost	COVID-19 Deaths
DESI Digital Public Services	0.612 **	0.443 *	0.502 **	−0.566 **
DESI Integration Digital Technology	0.609 **	0.489 **	0.678 **	−0.697 **
DESI Connectivity	0.439 *	0.327	0.564 **	−0.472 *
DESI Human Capital	0.681 **	0.589 **	0.646 **	−0.663 **
Global DESI index	0.711 **	0.555 **	0.703 **	−0.720 **

where * stands for significant correlation at the 0.05 level (2-tailed), while ** stands for significant correlation at the 0.01 level (2-tailed). Source: authors own computations.

As expected, the highest influence on youth employment is triggered by the DESI Human Capital index, with a strong correlation degree of over 68%. Our results seem to sustain the theory that better internet user skills of citizens and advanced skills of specialists facilitate access to better job opportunities (especially for young people), which would, therefore, stimulate employment. These findings are consistent with previous studies in the field (Kee et al. 2023; Pirzada 2013 and Picatoste et al. 2018), who brought evidence to support the theory that computer skills boost youth employability.

Moreover, the positive and significant association between youth employment and the DESI Integration Digital Technology index of almost 61% suggests that improvements in the e-commerce sector and increased usage of digital technologies in the business sector could also increase youth employment. Similarly, in terms of Digital Public Services, our results indicate that access to e-government and open data policies are also stimulating factors to higher youth employment, the DESI Digital Public Services being rather strongly correlated with youth employment (61.2%).

Finally, in the current transition to digitalization in the EU countries, factors like mobile and fixed broadband coverage should not be neglected, as they can improve the working conditions in the labor market and even facilitate working from home or flexicurity opportunities, which can also stimulate employment. The strength of the association between youth employment and the DESI Connectivity index is, however, moderate at only 44%.

In order to further investigate the relationship between the global digitalization level and youth employment, we also computed the global DESI index by aggregating its four dimensions using equal weights (as suggested by the DESI computation methodology) and rechecked the Pearson correlation test. The results indicate a high and positive relationship with youth employment of 71%, confirming that a high degree of digitalization naturally comes hand in hand with a boost of youth employment, higher labor costs, and increased productivity in the labor market. These findings are in line with previous literature as well. For instance, Kee et al. (2023) and Pirzada (2013) brought evidence in favor of higher employability due to communication and digital skills. This is further supported by Picatoste et al. (2018), who argued that IT skills, particularly computer skills, lead to higher youth employability.

The analysis was then extended to check the direction and intensity of the correlations between digitalization and the rest of the indicators considered in the analysis as well. In terms of labor market indicators, labor costs are significantly strongly correlated with DESI's dimensions regarding Human Capital and Integration of Digital Technology and only moderately correlated to DESI Digital Public Services and Connectivity. These results could indicate that investments in digital technology, as well as in human capital, might be reflected through higher labor costs. Our findings are consistent with those of Pirosca et al. (2021), who showed that digital proficiency, along with internet usage, has a direct impact on wages and salaries in the EU, having, therefore, further implications on total labor costs as well. They argue that people who cannot adapt to digital changes, have no internet access, or cannot work remotely are becoming a vulnerable category with low income and no college degree. Pirosca et al. (2021) thus emphasize the constant need for effective policy implementation to enhance digital education and training.

Moreover, digitalization seems to only indicate a moderate strength of association with labor productivity, especially reflected through the DESI's Human Capital dimension. Some evidence underlining how digital skills represent an increasing factor of productivity, particularly for remote work, can also be found in the work of Bloom et al. (2015), Spencer (2018), and Herman (2020).

One last notable aspect concerns the strong negative correlation between the COVID-19 pandemic impact (measured as COVID-19 deaths per total population) and the process of digitalization of the labor market. Neither the intensity nor the direction of the correlation shocks us, as already confirmed by the existing literature (Jackson et al. 2021).

Considering, however, the diversity of the EU member states in terms of digitalization of the labor market, we continued our investigation with a cluster analysis to search for patterns between the EU countries in the post-pandemic context. The dendrogram presented in Figure 5 illustrates the three detected EU country clusters that resulted from our analysis.

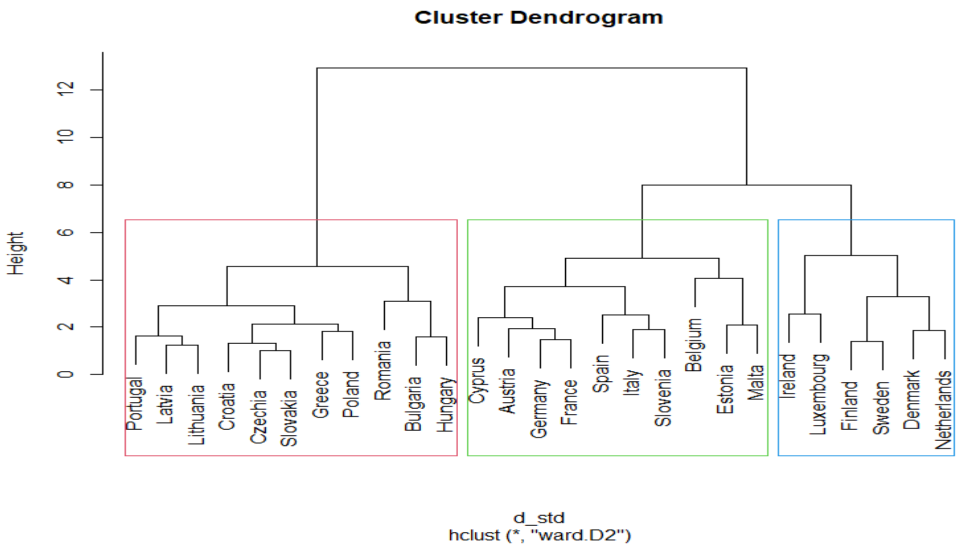

Figure 5. The dendrogram using R. Source: authors' own computation.

The established groupings are described using the centroid concept as follows:

- The high-tech economies cluster: Finland, Sweden, Denmark, the Netherlands, Luxembourg, and Ireland
- The medium-tech economies cluster: Germany, France, Austria, Cyprus, Slovenia, Italy, Spain, Malta, Estonia, and Belgium
- The low-tech economies cluster: Lithuania, Latvia, Portugal, Slovakia, Czechia, Croatia, Greece, Poland, Hungary, Bulgaria, and Romania

As can be noticed, the high-tech economies cluster includes economically prosperous nations, such as the Nordic countries, along with Luxembourg and Ireland. Among them, the Netherlands and Finland stand out by being the frontrunners in the EU in the shaping of their digital transformation process (in terms of the DESI index registered in 2022).

Our findings are consistent with previous studies. For instance, Ivanitskaia (2022) pointed out the same Nordic countries as those that resulted from our cluster analysis to stand out as leaders in terms of digitalization in the EU, estimating a significant negative impact of digitalization on the unemployment rate for these countries. Moreover, using the Eurobarometer 87.1 as the data set, Vasilescu et al. (2020) also identified the Nordic countries as having the highest share of people with good digital skills used both in daily life and at work.

Moreover, this first country-cluster registered in 2022 the highest values for the considered labor market indicators, having increased labor cost, along with high labor productivity and very high youth employment. In terms of youth employment, the Netherlands stands out again, followed by Denmark and Ireland. The highest labor costs are assigned to Luxembourg and Denmark, while the highest labor productivity is observed in Ireland and then in Luxembourg. The indicator that tracks fatalities from COVID-19 also showed the least unfavorable results when compared to the rest of the EU member states. In a similar way, each of the four DESI index dimensions has identified a substantial digital advance.

At the opposite pole, the low-tech economies cluster is the largest one, gathering 11 countries. It also registers the lowest values in terms of labor cost, labor productivity, youth employment, and degree of digitalization. Moreover, when considering the seriousness of the impact of the COVID-19 pandemic on the labor market, these nations also registered the highest number of deaths caused by COVID-19. As a general rule, the following three countries, Romania, Bulgaria, and Greece, are the last three in terms of the global DESI index and youth employment. Similarly, in a previous study, Vasilescu et al. (2020) found these low-income countries as the most digitally vulnerable countries in the

EU. However, Romania is noted to perform better than 70% of the other cluster countries in terms of labor productivity, having very low labor costs.

Through the prism of the centroids, the second cluster, represented by ten medium-tech economies with common traits, can be located in a neutral region with no extreme values. The nations included in this category do not stand out in terms of digitalization, but they are able to keep their values within acceptable bounds, like the labor market indicators, which average at an adequate level.

Among the medium-tech economies cluster, Cyprus, Italy, and Belgium seem to have the most to recover when shaping their digitalization process, especially in terms of integration of digital public services and in digitally transforming their human capital. Italy and Belgium, together with Spain, are also facing the lowest youth employment in the cluster, while Estonia and Cyprus are dealing with the lowest levels of labor costs and labor productivity.

When investigating cluster-country specificities in terms of digitalization, some notable aspects stand out (see Figure 6). For instance, among the high-tech economies cluster, Denmark distances itself significantly from the rest of the countries based on its digital infrastructure, considering both fixed and mobile broadband. The same can be said about Germany and Spain, which are among the second cluster countries, and Hungary and Romania, which are among the low-tech economies cluster.

In terms of intra-cluster country diversity, we clearly notice that both the medium- and low-tech economy clusters stand out with very high intra-cluster differences, especially when considering the Digital Public Services component. Thus, Estonia, Malta, and Spain (among the medium-tech economies cluster), as well as Lithuania, Latvia, and Portugal (among the low-tech economies cluster), are particularly noteworthy as having high demand and supply for e-government, as well as effective open data policies.

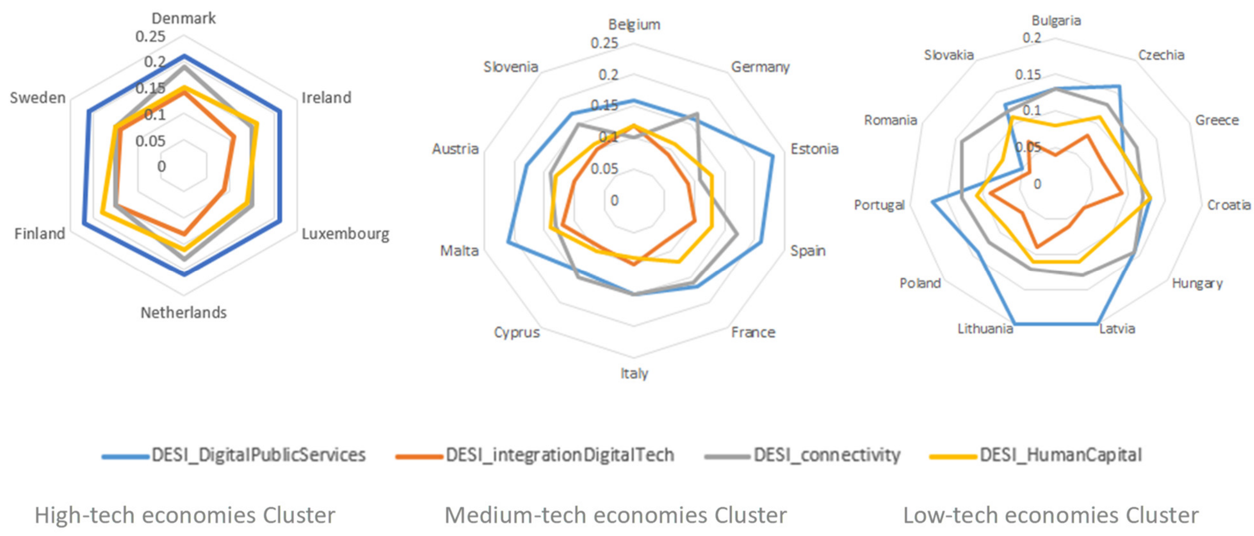

Figure 6. Cluster-country specificities in terms of digitalization in 2022. Source: authors' own computation.

Regarding the digitally adapted human capital, according to the DESI Human Capital dimension, among the high-tech economies cluster only Finland stands out with the most digitally skilled workers. Similarly, Pinto et al. (2023) pointed out that countries like Ireland and Sweden are digital access leaders in innovation due to research and development but still lack ICT professionals or widespread internet connectivity.

At the opposite pole, in the low-tech economies countries, there is more diversity and less convergence among the cluster countries. For instance, Romania, Poland, and Bulgaria have the most to recover as compared to the rest of the low-tech economies, requiring an effective digital policy framework to support youth workers in having access to digital training and education in order to improve their internet and digital skills required in the labor market.

Finally, in terms of digital technology integration, the following countries have fallen behind among their cluster countries: Luxembourg among the high-tech economies, France, Germany, Estonia, and Cyprus among the medium-tech economies, and Romania and Bulgaria among the low-tech countries, respectively.

Moreover, when comparing the overall digital performances of these three clusters, some final inter-cluster particularities stand out. For instance, we notice that the high-tech economies cluster is further apart from the other two clusters in terms of digitalization. One can notice that the least significant differences between the three clusters are met in terms of connectivity, while the most notable distances between clusters correspond to the degree of digitalization of human capital when considering the internet user skills of citizens and advanced skills of specialists. The low-tech economies cluster is also quite far apart from the high-tech economies cluster in terms of integration of digital technology through how much enterprises and e-commerce manage to take-up of selected technologies.

The practical implications of our findings are twofold. On the one hand, in terms of policy implications, we believe that through this paper, we shed some light on how the EU member states can objectively be classified between high-tech economies and medium- and low-tech economies, respectively, while outlining significant intra- and inter- cluster patterns, as well as country-specific issues. These results could be extremely helpful for decision-makers within each EU member state when building and implementing digital policies that could tackle those specific unsolved issues. For instance, some Nordic countries that are the digital leaders in innovation should still focus on enhancing digital proficiency and internet connectivity, while the low-tech countries have the most to recover in the digitalization process, needing urgent and effective digital policy framework to allow youth workers access to digital training and education. Youth employment would benefit the most from these policies once they enhance their digital skills, but as Pirosca et al. (2021) previously highlighted, increased digital proficiency would also lead to a more effective and flexible labor market.

On the other hand, for academics, we brought a more holistic approach and circumspect attitude in investigating the diversity of the EU member states in terms of digitalization of the labor market and in finding patterns between them.

6. Conclusions

Digital technologies are constantly being integrated into everyday life worldwide, playing, therefore, a crucial role in transforming both society in general and the labor market in particular. The EU requires digitally smart people in the labor market and has promoted this through the Digital Agenda and the EU Youth Strategy 2019–2027.

Taking these into consideration, our paper aimed to investigate the diversity of the EU member states in terms of digitalization of the labor market and to find patterns between the EU countries. Considering the post-pandemic context, we gathered a set of indicators at the EU level for the year 2022 from a multidimensional perspective to reflect not only the labor market specificities of each country but also the degree of digitalization and the COVID-19 pandemic impact upon each EU country. Among the labor market indicators, we considered relevant factors such as youth employment, labor cost, and labor productivity.

The Pearson correlation tests measured the strength of the association between digitalization and the labor market indicators, while the cluster analysis outlined some patterns for the high-tech EU economies versus the medium and the low-tech EU economies. As expected, the Nordic countries, along with Luxembourg and Ireland, were included in the high-tech economies cluster, with the Netherlands and Finland standing out by being the frontrunners in EU digital transformation.

Among the medium-tech economies cluster, Cyprus, Italy, and Belgium have the most to recover when shaping their digitalization process, especially in terms of integration of digital public services and digitally transforming their human capital.

Finland also stands out with the most digitally skilled workers, while at the opposite pole, Romania, Poland, and Bulgaria have the most to recover, requiring an effective digital policy framework to support youth workers have access to digital training and education in order to improve their internet and digital skills required in the labor market.

Overall, our analysis indicates some clear trends and particularities among the EU countries in terms of labor market performances and the integration of digital technologies. Digitalization is a challenging and demanding transition process that requires policy implementation and constant investments in digital technologies. Its impact on the labor market is multi-faced, permanently changing the digital job skills requirements in the labor market, especially for the youngest generations. Our findings are consistent with the international literature review and have the benefit of also considering in the analysis the impact of the post-COVID-19 pandemic on the EU economies.

In terms of research limitations, we are aware of the following two-fold caveats. First, the data set limitations considered in the cluster analysis could be argued. A trade-off between the quantity of indicators considered in the analysis and the quality of the cluster analysis results was made. However, we believe that the selected data set does quite well reflect the process of digitalization and the labor market specificities of each EU country, as well as the impact of the COVID-19 pandemic upon each country. Secondly, the cluster analysis can only reflect a static image of such a dynamic, transformative process that requires digital technology integration into everyday life. Even so, we believe that several specificities among the high-tech economies versus medium-tech and low-tech economies were spotted and properly highlighted in this paper. The practical implications of our study consist mostly of providing decision-makers directions on issues to tackle when implementing EU digital policies, while for academics, we offered a more holistic approach to study the digital diversity of the EU member states.

In future research, we intend to tackle the impact of digitalization of the EU labor market from a distinct methodological approach that will allow us to investigate it dynamically, using dynamic panel estimation. Additional indicators can also be considered to broaden the spectrum of indicators, and predictions on youth employment, labor cost, and productivity could be made in the context of digitalization.

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Appendix A

Table A1. The data set of the cluster analysis.

Country	L1	L2	L3	C1	D1	D2	D3	D4
Austria	28.6	115.7	63.9	0.002420014	0.18	0.1	0.14	0.13
Belgium	33.4	131.3	44.4	0.002861807	0.16	0.12	0.1	0.12
Bulgaria	7.1	54.6	38.5	0.005608412	0.13	0.04	0.13	0.08
Croatia	10.4	78.5	44.6	0.004362636	0.13	0.09	0.12	0.13
Cyprus	15.6	87.3	53.8	0.001404007	0.14	0.09	0.15	0.1
Czechia	12.5	84.9	44.6	0.00401668	0.16	0.08	0.13	0.11
Denmark	41	122.9	64.2	0.001322961	0.21	0.14	0.19	0.15
Estonia	12.2	82.8	55.1	0.002056462	0.23	0.09	0.11	0.13
Finland	29.6	105.9	57.2	0.001549431	0.22	0.15	0.15	0.18
France	27.7	110.3	48.6	0.002384012	0.17	0.08	0.16	0.12
Germany	30.3	102.7	61.7	0.001987985	0.16	0.09	0.17	0.11
Greece	11.6	68.9	33.1	0.003367944	0.1	0.07	0.12	0.1
Hungary	9.1	74.5	48	0.004865408	0.14	0.05	0.14	0.1
Ireland	31.8	224.5	58.7	0.001689392	0.21	0.11	0.15	0.16
Italy	21.2	105.3	33.8	0.00313008	0.15	0.1	0.15	0.09
Latvia	9.6	75.4	47	0.00378839	0.2	0.06	0.13	0.11
Lithuania	12.5	83.1	49.8	0.003447927	0.2	0.09	0.12	0.11
Luxembourg	44.4	162.2	49.6	0.001474673	0.21	0.09	0.15	0.14
Malta	13.6	91.2	69.8	0.001563868	0.21	0.12	0.13	0.14
Netherlands	30.7	108.8	79.3	0.001308129	0.21	0.13	0.18	0.16
Poland	10.3	85.1	48.1	0.002973946	0.14	0.06	0.12	0.09
Portugal	13	74.9	43.1	0.002509333	0.17	0.09	0.13	0.11
Romania	9	80.8	36.6	0.003427086	0.05	0.04	0.14	0.08
Slovakia	11.4	73.8	43	0.003689761	0.13	0.07	0.12	0.11
Slovenia	19.8	86.1	48.1	0.004151723	0.17	0.1	0.15	0.11
Spain	17.5	93.7	38.8	0.002500976	0.21	0.1	0.17	0.13
Sweden	27.3	115.5	57.2	0.002114443	0.21	0.14	0.15	0.15

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