Digital Economy and Youth Unemployment in the EU

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ABSTRACT

Aim. The aim of this research is to examine how various dimensions of the digital economy - namely, internet access, ICT-specific education, and digital workforce development - interact with educational and macroeconomic factors to influence youth unemployment across the EU. The study seeks to identify whether digitalisation serves as a lever to reduce youth joblessness and how its effects vary across countries.

Methods. This study employs an Ordinary Least Squares (OLS) regression based on country-year panel data for 27 EU countries over the period 2013–2023, in conjunction with K-means cluster analysis. The quantitative model integrates seven variables, including household internet access, ICT education, GDP growth rate, to estimate their influence on youth unemployment. Cluster analysis is used to group countries based on shared characteristics in digital readiness and employment outcomes.

Results. The regression results confirm that higher internet access and ICT education levels significantly reduce youth unemployment, while GDP growth plays a reinforcing role. General tertiary education showed a weak positive association with unemployment, suggesting potential skill mismatches. The cluster analysis revealed four distinct groups of countries, each with different digital profiles and policy needs.

Conclusions. The study concludes that digital infrastructure, ICT skills, and economic growth are important for reducing youth unemployment. However, digitalisation should be combined with labour market and education policies adapted to different country groups.

Practical Application. The results may support policymakers in designing coordinated strategies that link digital education, infrastructure, and macroeconomic reform to tackle youth unemployment.

Keywords: digital economy, youth unemployment, ICT education, digital divide, labour market

Introduction

Youth unemployment remains a pressing socio-economic challenge worldwide. High youth joblessness not only stifles economic growth but also exacerbates social inequalities and instability. In the European Union (EU), youth unemployment has persisted at elevated levels even after the recovery from the global financial crisis, and it spiked again during the COVID-19 pandemic. Policymakers have implemented various measures – from education and training programmes to labour market reforms – yet structural youth unemployment remains a tough problem. Moreover, ongoing geopolitical challenges such as the refugee crisis in the EU have placed additional strain on social systems and labour markets, indirectly affecting youth employment opportunities, particularly in host countries with limited integration capacity (Pop-

ovych et al., 2024).In this context, the rapid rise of the digital economy has attracted attention as a potential catalyst for improving youth labour market outcomes (Başol et al., 2023). It is also important to consider that youth labour integration is closely connected to value-based systems, particularly in relation to sustainability and purpose-driven work. Integrating spiritual and ethical values into employment policies and education can contribute to longer-term social sustainability (Kondrla et al., 2024). This implies that digital employment initiatives could be strengthened if aligned not only with economic objectives but also with societal values and holistic development. The digital economy encompasses the adoption of information and communication technologies (ICTs), the growth of online platforms and digital services, and the digitalisation of traditional industries. Digitisation is not only a technological shift but also a driver of human capital formation, competitiveness, and broader macroeconomic development (Shevchenko et al., 2023). Its expansion is reshaping the nature of work and the demand for skills across the globe.

Optimism has grown that digitalisation can offer new opportunities to tackle youth unemployment. The diffusion of digital technologies is associated with the emergence of new job sectors (for instance, in ICT services, e-commerce, and digital entrepreneurship) and new forms of work, such as the gig economy. These developments could *absorb* young workers into the labour market by lowering entry barriers and creating flexible work arrangements. For example, digital platforms for freelance and "gig" work have enabled many young people to find employment opportunities online, often transcending geographic constraints (Jeyaraj et al., 2024). This panel study covering 79 countries found that growth in the gig economy – measured by an online labour index – has a significant negative impact on youth unemployment, suggesting that greater digital platform activity reduces youth joblessness (Jeyaraj et al., 2024). Similarly, evidence from developing economies highlights the promise of digital expansion: in Nigeria, the burgeoning digital economy was found to explain about *67%* of the variation in youth unemployment rates, indicating a strong influence of digital development on youth labour outcomes (Idris & Maikomo, 2024). In China as well, research suggests that youth unemployment has significantly decreased as a result of digital economic growth, underscoring the potential of digital transformation to create jobs for young workers (Wu, 2023). These findings align with the view that the digital economy can be a boon rather than a threat to youth employment, by spurring job creation and improving labour market matching.

At the same time, a more cautious perspective notes that the digital revolution poses new challenges and risks for young job seekers. The advance of automation, artificial intelligence (AI), and other labour-saving technologies has raised concerns about technological unemployment, wherein technology substitutes for human labour on a large scale (Lima et al., 2021). Moreover, the digital divide – disparities in access to digital tools and skills – could mean that the benefits of the digital economy are unevenly distributed. Without inclusive access and training, digitalisation might further marginalise less-connected youth and those lacking digital skills, actually widening unemployment gaps.

Within Europe, these debates take on special relevance. The EU has embraced a digital strategy to boost competitiveness and inclusion (European Commission, 2023). Europe's youth unemployment problem has been persistent, with some countries (especially in Southern and Eastern Europe) struggling with youth jobless rates well above the EU average. This raises the question of whether higher digital development translates into better employment outcomes for young Europeans. The EU countries that advanced further in digital infrastructure, digital skills, and online services tended to see lower youth NEET and unemployment rates, suggesting that digitalisation can help mitigate youth joblessness in the European context. However, research in this area is still emerging, and important nuances remain unexplored. For instance, it is unclear which facets of the digital economy (connectivity, skills, digital industries, etc.) are most consequential for youth employment, or how digital inclusion policies might moderate these effects.

Against this backdrop, the current study examines the relationship between the digital economy and youth unemployment in the EU, thereby addressing a pertinent research gap. While various global and national studies have analysed digitalisation and employment, there is a need for a focused investigation that integrates both global insights and EU-specific dynamics.

The study aims to examine the relationship between various digital economy indicators, educational factors, and economic performance, assessing their combined influence on youth unemployment rates.

By reviewing the literature and analysing recent data, this paper seeks to shed light on whether the digital economy is indeed improving youth employability in Europe, and what challenges must be managed to ensure inclusive benefits. The study's findings will not only contribute to scholarly understanding of digital-era labour markets but also inform policymakers as they craft strategies at the intersection of digital transformation and youth employment. The remainder of this article is organised as follows: first, we review the relevant literature on the digital economy's labour market impacts, the role of ICT access and skills in youth employability, and evidence from Europe. We then identify key gaps and formulate the specific questions guiding this research.

Literature Review

The Digital Economy and Labour Market Impacts

The term digital economy generally refers to economic activities enabled by digital technologies and the internet, encompassing everything from ICT industries and e-commerce to the digitalisation of traditional sectors. Over the past two decades, the digital economy has grown exponentially, becoming a major driver of in-

novation and productivity. The Organisation for Economic Co-operation and Development (OECD) provides a broad definition of the digital economy, which encompasses all economic activity reliant on or enhanced by the use of digital inputs, including digital technologies, infrastructure, services, and data (OECD, 2021). In essence, it covers not only tech sectors but also the diffusion of digital tools across all industries, which blurs the line between "digital" and "traditional" economies. This digital transformation has profound implications for labour markets. On the one hand, digitalisation can create new jobs and demand for skills. It has the potential to reshape employment structures and leads to an increase in the labour share and benefiting upstream and downstream sectors, which is crucial for addressing potential negative impacts on the labour share in the future (Wang et al., 2024).

Also, the digital economy has reshaped employment structures, favouring the tertiary sector from both sectoral and skill perspectives, and leading to an evolutionary process from a monotonically upgrading effect to "polarisation" in emerging market countries (Qu & Fan, 2024). The study of 30 emerging market countries between 2006 and 2020 found that the digital economy's impact on the employment structure displays discernible heterogeneity and stage-specific characteristics, with discernible implications for policymakers and businesses (Qu & Fan, 2024).

Digital sectors (such as software development, It services, digital marketing, and platform-based companies) are expanding rapidly and tend to employ a high share of young, tech-savvy workers. Additionally, technology can complement labour by improving productivity and generating growth, which indirectly leads to job creation in the wider economy. Many researchers highlight that digital innovation often brings forth new occupations and opportunities that did not exist before, offsetting some of the jobs lost to automation (Lima et al., 2021). For example, the rise of app-based services and the gig economy has allowed youth to engage in freelance work, gig tasks, and online entrepreneurship at an unprecedented scale.

Empirical studies increasingly provide evidence of positive employment effects from digital development, including in youth labour markets. In particular, digital platforms and online labour markets can create new employment channels for young people by reducing geographical barriers and expanding access to flexible work opportunities. A cross-country analysis of 79 countries using a dynamic panel model showed that higher digital gig activity, measured by the Online Labour Index, significantly reduces youth unemployment rates (Jeyaraj et al., 2024). In a similar vein, country-specific research in emerging economies underscores the benefits of digital growth. In Nigeria, where youth unemployment is a critical issue, a recent study reported that inclusion of a digital economy indicator in an econometric model improved explanatory power dramatically – accounting for about 67.3% of the variation in youth unemployment (Idris & Maikomo, 2024). The Nigerian case showed a strong inverse relationship between the expansion of ICT usage/

digital infrastructure and youth unemployment outcomes, even though not all ICT sub-indicators were individually significant. And in China, the structural transformation toward a digital economy has been linked to falling youth jobless rates; one analysis indicates that the development of the digital economy has contributed to a *significant decrease* in youth unemployment in China in recent years (Idris & Maikomo, 2024). These examples illustrate a consistent pattern: embracing digitalisation tends to correlate with better youth employment prospects, likely by spurring new industries (e.g. ICT, online services) and by modernising existing ones.

Daniel Lederman and Marwane Zouaidi confirmed that the impact of the digital economy on unemployment across a global sample of countries indicates a robust, negative partial correlation between national unemployment rates and the incidence of the digital economy, suggesting the potential for a higher impact in developing than high-income economies (Lederman & Zouaidi, 2022).

On the other hand, the literature also cautions about the disruptive effects of digitalisation on employment. The concept of technological unemployment, famously discussed by Keynes and revisited by modern economists, refers to job losses caused by technological change. Today, advanced automation and AI pose this risk. Carl Benedikt Frey and Michael A.Osborne (2017) ignited debate with their finding that nearly half of U.S. occupations were susceptible to automation.

Although other studies using refined methods (accounting for task adaptability and new job creation) produced lower estimates – for example, an OECD study found about 9% of jobs in OECD countries are at high risk of automation (Arntz et al., 2016) – there is consensus that *all* economies will feel some impact of automation on work. Young workers may be relatively adaptable to new technology, but they are also concentrated in certain routine or entry-level roles (such as retail, food service, and administrative support) that are increasingly being automated or digitised (through self-service kiosks, algorithms, etc.). Thus, without upskilling, some youth could face displacement. Importantly, digitalisation can also change the quality of jobs available to youth. While gig and platform-based work can provide income, they sometimes come with precarious conditions (low security, lack of benefits).

Some researchers also argued that digitalisation can have complex effects – without inclusive skill development, automation and digital change may displace certain jobs, posing risks especially to less-educated or low-income youth (Crisan et al., 2023).

In summary, the net effect of the digital economy on youth employment, as evidenced by prior studies, is a balance of opportunity and disruption. The optimistic strand of literature documents numerous cases where digital progress has coincided with lower youth unemployment, while the *critical* strand points out that without complementary policies (like skills development and social protection), digitalisation could exclude segments of youth or degrade job quality. This dual perspective sets the stage for examining how these dynamics play out in the European context.

ICT Access, Digital Skills, and Youth Employability

A recurring theme in research is that access to technology and digital skills are now key determinants of a young person's employment prospects. ICT penetration in a society lowers the unemployment rate and helps grow the economy of a country (Hussain et al., 2021; Mossberger et al., 2021).

As job searching and hiring processes become increasingly digital (through online job boards, e-recruitment, LinkedIn networking, etc.), those without internet access or basic digital literacy are at a severe disadvantage in the labour market (Oyedemi & Choung, 2020).

A consistent finding in recent studies is that strong digital skills tend to improve youth employability. Across diverse contexts, digital competencies have emerged as critical assets in securing jobs. For example, in Malaysia, a survey of employers indicates that the top in-demand skills for graduates are digital literacy and problem-solving, and that equipping young people with these digital skills is essential for their success in current and future jobs and for lowering youth unemployment rates **(**Tee et al., 2024).

In Romania – an EU member with high youth unemployment and one of the lowest digital economy index rankings – researchers point out that a lack of digital literacy is a barrier to youth employment, and stress the need to equip young people with the digital skills required for jobs in an increasingly digitalised economy **(**Barna & Epure, 2020**).**

Toks Dele Oyedemi and Maphuthi Choung (2020) frame digital access as a form of cultural capital that can either facilitate or hinder employment opportunities in a study of South African youth. They found that limited access to the internet for job-seeking purposes remains a significant challenge for many unemployed youth in South Africa, resulting in frustration and discouragement among these job seekers (Oyedemi & Choung, 2020). In their interviews, young people expressed that not being able to go online easily to look up job postings or submit applications meant missing out on opportunities that others (with better digital access) could pursue. This concept of digital inequality feeding into employment inequality is a growing concern, especially as more public services (including job centres and application portals) move online. The South African case underscores that bridging the basic digital divide (ensuring affordable internet and devices) is a precondition to reduce youth unemployment in the digital era.

Quantitative evidence further reinforces the importance of ICT access for youth employment. A recent study in Cameroon assessed how internet use affects job acquisition among young people. Using nationally representative survey data, the study found that internet use increases the probability of finding a job among youth by an estimated 15% to 31%, depending on the model specification (Nouffeussie et al., 2024). Young internet users were many times more likely to be employed than their

peers who did not use the internet. Notably, the study compared this effect between younger and older workers and concluded that the digital advantage in job-finding was much larger for youth (15–35 years) than for older adults (Nouffeussie et al., 2024). This suggests that internet proficiency and engagement (e.g. using social media, online job platforms, etc.) have become especially crucial for the younger generation's employment, likely because young people are more present in online networks where job information circulates, and because many entry-level jobs now require at least basic digital skills. The Cameroonian study contributes to understanding the digital divide not just as a binary of access, but also in terms of generational differences in benefiting from digital tools. It implies that efforts to get youth online (through improved infrastructure and affordable data) can yield tangible employment benefits. Similar patterns have been observed elsewhere in Africa and Asia, reinforcing that the empowerment of youth through ICT is a viable strategy to improve their employment outcomes.

Beyond access, the quality of digital skills and literacy that youth possess is important. As the nature of work changes, a baseline of digital literacy (ability to use computers, navigate the internet, handle digital communication) is often considered a requirement for most decent jobs. More advanced skills, such as coding, data analysis, digital marketing, or simply proficiency in office productivity software, can significantly enhance a young candidate's employability. Recent studies further underscore that fostering digital creativity, rethinking knowledge models, and applying inclusive pedagogical strategies are essential to prepare youth for the digital labour market (Dervishaj & Presi, 2024; Kobylarek, 2024; Presi et al., 2024). Many countries have launched digital skills training initiatives targeting young people. The EU, for example, has various programmes under its Digital Education Action Plan and the Youth Guarantee. The goal of this programmes is to improve young people's digital competencies, acknowledging that skill gaps are a barrier to filling jobs in tech-driven sectors (European Commission, 2021). In the literature, there is evidence that such targeted skill development can make a difference. A case study from Nigeria provides illustrative insights through the evaluation of the "Double Your Digital Skills Initiative", a pilot programme offering short-term intensive training in various digital skills to young people (Tunji-Olayeni et al., 2021). The study found extremely high interest among youths (especially those aged 19–24 and university students) in acquiring digital skills, with digital marketing being the most in-demand skill choice. This reflects a recognition among young people that such skills are "a necessity for wage employment and in the creation of a personal business" in an increasingly digitalised economy. However, the authors also pointed out that many youths currently lack the requisite digital skills to use technology productively for employment. The results from the pilot were promising, and the "lessons learned" suggest that scaling up digital skill training (in partnership with stakeholders like universities, private tech companies, and government agencies) can help better prepare youth for the digital job market.

Lacking digital access or skills can exacerbate youth unemployment, whereas digital proficiency enhances job prospects. Indeed, multiple studies concur that ICT and computer skills boost youth employability (Crisan et al., 2023).

In the European context, digital skill levels among youth are generally high in basic terms (today's youth are often considered *digital natives*).

Policymakers are therefore pushing for improvements in digital education at all levels – from integrating digital literacy in school curricula to promoting coding academies, ICT vocational training, and digital apprenticeships for youth. The literature supports the notion that such investments in human capital are crucial. Evidence from Spanish youth shows that social innovation programmes combining digital training with mentorship can enhance youth employability. In particular, tailored digital skill development, together with soft skills training and networking support, helped unemployed young people transition into jobs in the digital age (Enciso-Santocildes et al., 2021). Thus, both access and skills form the twin pillars of improving youth employability in the digital economy. Where access to ICT is lacking, basic infrastructure and inclusion policies are needed; where basic access is in place, the focus shifts to elevating skill levels and ensuring alignment with market needs. Our review indicates that countries which succeed on both fronts – broad digital inclusion and strong digital skill-building – tend to see more favourable youth employment outcomes.

In conclusion, the literature firmly establishes that the digital economy is reshaping youth employment in significant ways, offering both opportunities and challenges. The consensus is that digitalisation is highly relevant to youth labour market outcomes: it can be a powerful tool to combat youth unemployment if leveraged correctly, but it can also exacerbate inequities if its proceeds are unevenly distributed. The present study builds on this foundation by specifically focusing on the EU context, where comprehensive data and a diversity of country experiences provide a fertile ground for analysis.

Based on the preceding analysis, we have formulated three hypotheses regarding the dependency of youth unemployment on the digital economy:

- H1: Greater digital infrastructure and connectivity are associated with lower youth unemployment. Tested with: Household Internet Access (%), Enterprises Providing ICT Training (%)/
- H2: Higher levels of digital and tertiary educational attainment among young people are associated with reduced youth unemployment. Tested with: ICT-Educated Youth Employment (%), Tertiary Education Attainment (%), ICT Specialists in Employment (%).
- H3: Youth unemployment is influenced by macroeconomic conditions and structural labour market factors. Tested with: Real GDP Growth Rate (%), Average Full-Time Adjusted Salary (EUR).

These hypotheses are designed to reflect broader theoretical constructs that connect education, digital transformation, and social outcomes.

Methodology

This study adopts a quantitative research design utilising an Ordinary Least Squares (OLS) regression and Cluster Analysis to investigate the impact of the digital economy, education, and economic factors on youth unemployment across EU countries.

This mixed-methods approach ensures comprehensive insights by:

- Assessing the statistical association between digital economy indicators and youth unemployment using regression analysis;
- Identifying patterns and country clusters based on digital readiness, economic performance, and educational attainment through cluster analysis.

An OLS regression model based on country-year panel data is used to analyse the statistical association between digital economy indicators and youth unemployment. The model allows us to examine whether variation in digital, educational, labour-market and macroeconomic indicators is associated with variation in youth unemployment across EU countries and years. The panel structure of the dataset makes it possible to account for both cross-country and temporal variation over the 2013–2023 period. The study relies on publicly available data from Eurostat to ensure accuracy, consistency, and coverage across EU countries from 2013 to 2023. The selected variables are chosen based on their relevance to digital economy indicators, youth unemployment, and economic performance (Appendix A, Table A1).

In this study, we cluster European countries based on (a) household internet access (% of households), (b) employed persons aged 15–34 with an ICT education (% of youth employment), and (c) youth unemployment rate (% of labour force aged 15–24). These three indicators were chosen to capture a multidimensional profile of a country's digital infrastructure, digital skills in the young workforce, and success in integrating youth into employment. Prior research and policy reports emphasise the interplay of these factors – for example, lack of digital skills is cited as a contributor to high youth unemployment (Petrescu et al., 2024), while strong digital competencies can enhance youth employability (Crisan et al., 2023). By clustering countries on these dimensions, we aim to identify distinct groups with similar digital development and youth employment outcomes, providing insights into regional disparities and informing targeted policy responses.

To focus on long-term country characteristics and reduce short-term volatility, we computed the country-level average of each indicator over the 2013–2023 period. This yields a single representative value for each country on each variable (e.g. average household internet access over 2013–2023). Using the multi-year average smooths out year-to-year fluctuations and captures the general level of digital access, ICT-skilled youth workforce, and youth unemployment for the country over the past decade.

Since the three indicators are on comparable percentage scales but with different value ranges and variability, we standardised each of the three variables (z-score stan-

dardisation). This transformed each indicator to mean 0 and standard deviation 1 across the 27 countries. Standardisation ensures that K-means clustering – which uses Euclidean distance – gives equal weight to each dimension and is not unduly influenced by one indicator's scale. The standardised dataset is a 27×3 matrix (27 countries, 3 features) in which each feature contributes proportionately to distance calculations.

We applied the K-means clustering algorithm to identify groups of EU countries with similar digital and youth employment profiles. K-means assigns observations to the nearest cluster centroid and iteratively updates centroids to minimise within-cluster sum of squared errors (SSE). Since the method requires the number of clusters to be specified a priori, we estimated alternative solutions for k = 1 to k = 10 and evaluated them using the Elbow method and silhouette analysis. The Elbow method was used to identify the point at which further increases in k generated only marginal reductions in SSE. Silhouette analysis assessed cluster cohesion and separation, with values ranging from −1 to 1 and higher scores indicating better-defined clusters (Mamat et al., 2018). The final cluster solution was selected by combining these statistical criteria with substantive interpretability. Figure A1 in Appendix A reports the Elbow and silhouette results used to determine the optimal number of clusters. The Elbow plot indicates a clear reduction in within-cluster SSE up to k = 3–4, after which additional clusters provide only marginal improvement. Although the highest silhouette score was observed for k = 2, the scores for k = 3 and k = 4 remained relatively close and acceptable, at approximately 0.355 and 0.350, respectively. Therefore, the four-cluster solution was selected, as it offered a stronger balance between statistical fit and substantive interpretability, including the identification of a distinct high-youth-unemployment group. K-means was then re-estimated with k = 4 using the standardised variables, and the resulting centroids and country memberships were analysed in both standardised and original units.

It is important to clarify the relationship between the regression and clustering datasets. Both analyses are based on the same EU-27 country sample and cover the same period, 2013–2023. The regression analysis uses the full country-year panel dataset, consisting of 297 observations, calculated as 27 countries observed over 11 years. These observations do not represent individual-level respondents, but country-year observations. In contrast, the K-means cluster analysis uses country-level averages calculated over the full 2013–2023 period for each country. Therefore, the clustering dataset consists of 27 country-level observations and three averaged variables. This approach allows the regression analysis to capture annual variation, while the cluster analysis provides a complementary long-term country typology. The relationship between the two datasets is summarised in Appendix A, Table A2.

The cluster analysis is not intended to replace or directly test the regression relationships. Rather, it is used as a complementary country-level typology that contextualises the regression findings by grouping EU countries according to their long-term digital and youth labour-market profiles.

Results

The ordinary least squares (OLS) regression analysis was conducted to examine the relationship between digital economy variables and youth unemployment across 297 observations. The model includes seven independent variables representing digital infrastructure, education, labour characteristics, and economic performance.

Descriptive statistics for the variables included in the final OLS regression model are reported in Appendix A, Table A3. The table confirms that the regression dataset contains 297 country-year observations and shows sufficient cross-country and temporal variation in the analysed variables.

$R^2 = 0.364$ and Adjusted $R^2 = 0.349$, indicating that approximately 35% of the variation in the youth unemployment rate is explained by the model.

The model is statistically significant overall ($F(7, 289) = 23.66$, $p < 0.0001$). It shows strong explanatory power (Appendix B, Table B1). As we can see Significant Variables are X1: Household Internet Access (%), X3: Employed Persons with ICT Education (%), X6: Real GDP Growth Rate. X4: Tertiary Education Attainment (%) has Marginal significance. So we leave these variables for further study and run the regression calculations again.

The model demonstrates good explanatory power with an R^2 value of 0.355 and an Adjusted R^2 of 0.346, indicating that approximately 35% of the variance in youth unemployment rates across 297 observations is explained by the four independent variables included (Appendix B, Table B2).

The model is statistically significant overall, as confirmed by the F-statistic**.** The standard error of the estimate is 8.11, suggesting a reasonably precise model fit given the cross-national and multi-year data.

We obtained such results (Table 1).

Table 1

Regression Coefficients and Statistical Significance

Variable	Coefficient (β)	p-value	Interpretation
Intercept	86.25	< 0.001	Predicted youth unemployment when all predictors are zero (theoretical baseline).
X1: Household Internet Access (%)	-0.695	< 0.001	Strong and highly significant negative effect: for every 1 percentage point increase in household internet access, youth unemployment decreases by ~0.70 percentage points.
X3: Employed Persons with ICT Education (%)	-0.149	0.010	Statistically significant: as the proportion of ICT-educated young workers increases, youth unemployment significantly decreases.

Variable	Coefficient (β)	p-value	Interpretation
X4: Tertiary Education Attainment (%)	+0.200	0.022	Statistically significant but positive: higher tertiary education levels among youth are associated with higher unemployment, possibly indicating overqualification or mismatch with job market demands.
X6: Real GDP Growth Rate (%)	-0.438	< 0.001	Strong and significant effect: economic growth is associated with a reduction in youth unemployment.

Source. Own research.

As a result, the following regression was obtained and approved:

(1)

These findings reinforce the multifaceted role of the digital economy in shaping youth labour outcomes. While higher education alone does not guarantee employment, the combination of digital connectivity, targeted ICT education, and economic growth creates a favourable environment for improving youth labour market integration.

The strong significance of internet access and ICT employment underlines the need for policy efforts that integrate digital infrastructure with youth training and employment strategies.

The results of the statistical hypothesis testing indicate that the empirical evidence generally supports the proposed research assumptions. Hypothesis 1 and Hypothesis 3 were fully supported, while Hypothesis 2 was only partially supported. This suggests that most of the expected relationships were confirmed, although the evidence for one hypothesis was mixed and requires a more cautious interpretation.

We conducted a cluster analysis to assess on (1) household internet access (% of households), (2) employed persons aged 15–34 with an ICT education (% of youth employment), and (3) youth unemployment rate (% of labour force aged 15–24).

The country-level averaged indicators used as inputs for the K-means procedure are reported in Appendix B, Table B3. These values represent the average position of each EU country over the 2013–2023 period and serve as the empirical basis for the cluster membership reported below.

Descriptive statistics for the country-level variables used in the K-means cluster analysis are reported in Appendix B, Table B4.

After conducting a cluster analysis, we obtained 4 clusters of EU countries, which show clear patterns in terms of digital access, skills, and youth unemployment.

The cluster analysis identified four distinct groups of EU countries with different combinations of digital access, ICT-related human capital, and youth unemployment. Cluster 1, "Digitally Advanced, Low Unemployment," includes Germany, the Netherlands, Sweden, Denmark, Finland, Austria, Ireland, and Luxembourg. These countries combine very high household internet access, averaging approximately 93%, with low youth unemployment, around 14%. The Netherlands

and Luxembourg represent the most digitally connected cases in this group, while Germany, Austria, and the Nordic countries illustrate the role of strong labour market institutions and diversified economies in supporting youth employment. Despite having the lowest share of ICT-educated youth among the clusters, this group shows that broad digital literacy and robust labour markets can compensate for a lower concentration of specialised ICT education.

Cluster 2, "High ICT Skills, Moderate Economy," includes Bulgaria, Croatia, Cyprus, Portugal, Romania, Slovakia, and Lithuania. This group is characterised by the highest share of ICT-educated youth, around 77%, but only moderate internet access and relatively high youth unemployment, around 23%. Lithuania, Romania, and Bulgaria illustrate the presence of strong ICT-oriented human capital, while Portugal, Cyprus, and Croatia reflect the continuing importance of broader economic and labour market constraints. This suggests that ICT-related human capital alone is insufficient unless supported by stronger digital infrastructure and broader job creation.

Cluster 3, "Moderate Access and Skills, Low Unemployment," includes Belgium, France, Estonia, Czechia, Poland, Slovenia, Hungary, Latvia, and Malta. These countries show relatively balanced digital profiles, with high internet access, around 85%, strong ICT-educated youth levels, around 74%, and low-to-moderate youth unemployment, around 15%. Estonia and Malta stand out as digitally dynamic small economies, while Czechia and Poland illustrate how improving economic performance can support favourable youth labour outcomes even with moderate digital indicators. This cluster indicates that balanced digital development, rather than digital leadership alone, can be associated with successful youth employment outcomes.

Cluster 4, "High Youth Unemployment Crisis," consists of Greece, Spain, and Italy. This group has relatively developed digital infrastructure, with internet access averaging around 81%, and moderate ICT-educated youth levels, around 71%, but extremely high youth unemployment, around 38%. Spain and Greece represent the most severe cases of youth unemployment during the analysed period, while Italy illustrates the persistence of structural labour market barriers despite relatively developed digital access. This indicates that digital readiness cannot offset deep macroeconomic and institutional weaknesses on its own.

Overall, the cluster results show that digital infrastructure and ICT education are important, but they do not automatically translate into lower youth unemployment. Their effects depend on broader economic conditions, labour market capacity, and the ability of countries to convert digital potential into employment opportunities. The clusters can be visualised in Figure C1 in Appendix C.

From these figures, one can clearly see the digital-development divide between Western/Northern Europe and much of Eastern Europe: the former has higher internet penetration but fewer ICT specialists, while the latter has slightly lower connectivity but a surplus of tech-educated youth. Interestingly, these two groups had comparable

youth unemployment outcomes in the 2013–2023 period – if anything, some Eastern countries in Cluster 2 still struggled with higher joblessness despite their tech talent.

To further illustrate cluster differences, Table 2 presents the average values of the three indicators in each cluster (centroid coordinates), along with example countries:

Table 2

Cluster Centroids (Mean Values) and Example Member Countries

Cluster (Label)	Household Internet Access (%)	ICT-Educated Youth (%)	Youth Unemployment (%)	Member Countries (examples)
Cluster 1: Digitally Advanced, Low Unemployment	93.1 (very high)	59.2 (low)	14.3 (low)	DE, NL, SE, DK, FI, IE, AT, LU (North/West Europe)
Cluster 2: High ICT Skills, Moderate Economy	78.5 (moderate)	77.4 (very high)	22.8 (moderately high)	BG, RO, HR, PT, CY, LT, SK (East/South Europe)
Cluster 3: Moderate Access & Skills, Low Unemployment	85.5 (high)	73.5 (high)	15.2 (low)	FR, BE, CZ, PL, HU, EE, LV, SI, MT
Cluster 4: Youth Unemployment Crisis (Southern)	81.2 (high)	70.8 (moderate)	38.4 (extremely high)	GR, ES, It (Southern Europe)

Source. Own research.

Clustering by these indicators provided a lens to understand how digital development interacts with labour market outcomes. The analysis shows that while strong digital infrastructure and education are common features of better-performing countries, they must coincide with healthy economic conditions to yield low youth unemployment. This has important implications for policymakers – investments in broadband and ICT training should be coupled with macroeconomic and labour market reforms. Encouragingly, our results also suggest that countries can improve: many Eastern members that once lagged in both internet access and youth employment have sharply improved their standings through concerted efforts, moving into more favourable clusters.

Each cluster suggests different policy priorities. Cluster 1 countries, while performing well, might focus on maintaining their edge in innovation, for instance, encouraging more youth to pursue advanced digital specialities (since a smaller share currently do) to meet the needs of emerging technologies and avoid skill shortages. Cluster 2 countries should capitalise on their strong human capital by improving digital infrastructure and the business climate: increasing rural broadband access, supporting startups, and integrating ICT talent into industry could help reduce the still-elevated youth unemployment. For Cluster 3, policies that sustain the momentum are

key – these countries have a balance of factors now, so continued investment in both education and job creation (especially in knowledge-based sectors) could solidify their gains. Finally, Cluster 4 countries require comprehensive economic reforms and targeted youth support. Their digital foundations are relatively solid, so the focus must be on economic diversification, reducing barriers to youth employment (like excessive temporary contracts or skill mismatches), and ensuring that digital skills translate into actual jobs. EU-level support and sharing of best practices (for example, learning from Germany or the Netherlands in vocational training or apprenticeships) could aid these high-unemployment states.

In all clusters, the interplay of digital access and education with employment highlights that digitalisation is a necessary but not sufficient condition for positive youth outcomes – it works in tandem with macroeconomic health and governance.

Discussion

The regression results indicate that digital economy development has a significant ameliorative effect on youth unemployment. Specifically, higher household internet access is associated with lower youth unemployment, suggesting that improved connectivity eases job search frictions and enables new forms of work (e.g. remote jobs and online entrepreneurship). Similarly, a greater share of employed persons with ICT education corresponds to a reduction in youth joblessness. This implies that when more workers (especially young workers) possess digital skills and qualifications, labour markets can better absorb young job seekers into emerging technology-driven roles. Finally, robust GDP growth is linked to declining youth unemployment, a relationship consistent with macroeconomic theory and prior evidence that economic expansions generate employment opportunities for youth (Ogbonna et al., 2023). Similarly, a cross-country analysis by Lederman and Zouaidi (2022) reported a robust negative correlation between national unemployment rates and digital adoption (proxied by online payments usage), with even larger unemployment benefits in developing economies than in advanced ones. In essence, strong economic growth, coupled with digital infrastructure and skills development, creates a favourable environment for youth employment, as each of these factors contributes to greater labour demand and improved employability among young people.

These findings reinforce the notion that digital transformation can be a catalyst for youth labour market inclusion. The significant negative coefficients on internet access and ICT-trained employment suggest that investments in digital connectivity and education directly benefit youth employment outcomes. In practical terms, widespread household internet access may help young people find jobs more efficiently (through online job platforms, social networks, and gig economy opportunities), while a workforce enriched with ICT-educated individuals is likely to attract and cre-

ate more digital-economy jobs that engage younger employees. In addition, Artem Artyukhov (2025) suggest that immersive university environments can extend digital education beyond conventional online learning, creating more interactive forms of competence development that may strengthen graduates' preparedness for digitally transformed labour markets (Artyukhov et al., 2025). The positive impact of GDP growth provides a macro-level confirmation that a rising economic tide "lifts all boats," including those of younger workers – a pattern in line with Okun's law (where growth reduces unemployment) and observed to be particularly strong for youth in many economies (Ogbonna et al., 2023). Strong growth can "lift all boats," including those of young job seekers, by increasing overall labour demand. Conversely, sluggish growth or recessions hit youth the hardest, as seen during the COVID-19 crisis when global youth employment fell sharply (International Labour Organization [ILO], 2020). Evidence from Slovakia confirms this dynamic: the COVID-19 crisis had a disproportionate impact on youth-intensive industries like education and tourism, underscoring how external shocks can severely hinder employment pathways for young people despite ongoing digitalisation (Petrikovičová et al., 2023). Our results reaffirm that a healthy economy is an important pre-condition for youths to benefit from digital advancements; digital infrastructure and skills yield the greatest dividends for youth employment when the economy is expanding to absorb new labour market entrants.

Overall, the results paint a coherent picture: expanding the digital economy and sustaining economic growth work in tandem to substantially reduce youth unemployment by both increasing the supply of skilled, tech-savvy labour and the demand for such labour in a growing economy.

Our results agree with a wide range of studies in illustrating a positive loop between youth upskilling in ICT and better employment outcomes (Crisan et al., 2023; Ouko et al, 2022). Notably, even firms are recognising this link: the share of enterprises offering ICT training, one of our regressors, can be seen as indicative of a country's commitment to developing digital skills. While our model did not show a strong standalone effect for this variable, its inclusion underscores what policy reports have argued: lack of digital skills among youth is a contributor to high youth unemployment, and promoting training opportunities is key to bridging that gap.

Meanwhile, the cluster analysis of EU countries provides additional insight by revealing groupings that mirror the digital divide in youth employment outcomes. We identified, for example, a cluster of countries with high internet penetration, a digitally skilled youth workforce, and low youth unemployment. These are likely the Northern and Western European countries that have invested heavily in digital infrastructure and education, a pattern consistent with the literature. Such countries illustrate how digital readiness coincides with better integration of youth into jobs, corroborating studies that find digitalisation is the "strongest policy" against youth joblessness in advanced economies (Basol et al., 2023). In contrast, another cluster

comprises countries with lower connectivity, fewer ICT-educated youth, and higher youth unemployment, such as some Southern or Eastern European states. This aligns with observations that regions lagging in digital development tend to face worse youth labour outcomes. Oyedemi and Choung (2020) describe how digital inequality (gaps in internet access and literacy) can exacerbate youth unemployment, since youths without access or skills are at a severe disadvantage in modern job markets.

Our findings reinforce the optimistic narrative that digital economy growth and youth labour market inclusion go hand-in-hand, while also underscoring the importance of complementary measures (education, training, structural reforms) that other studies have highlighted to ensure no youth is left behind in the digital era. Additionally, youth unemployment is often intertwined with broader social determinants, such as mental health and well-being. Research has shown that prolonged joblessness among youth can significantly worsen psychological health, decrease motivation, and increase social isolation, particularly in vulnerable populations engaged in social services or marginalised communities (Buzalova et al., 2024). Integrating mental health considerations into digital employment strategies may therefore improve the efficacy of interventions, especially in regions where social service workers report burnout and work-life imbalance.

The clustering results should be interpreted as complementary to the regression analysis. While the regression model captures annual country-level variation and estimates the association between digital economy indicators and youth unemployment, the cluster analysis summarises long-term structural differences between countries. Therefore, the cluster typology helps to contextualise the regression findings, but it should not be interpreted as an independent causal test.

While the findings are robust and illuminating, this study has several limitations that must be acknowledged. First, there are unobserved factors and omitted variables that could influence youth unemployment but were not included in our regression. Secondly, while Panel Data Analysis is a powerful tool for studying changes over time, it has limitations - it assumes that the impact of independent variables is constant over time, which may not be. Finally, the generality of our findings invites further exploration. We have treated countries (or regions) somewhat uniformly in the regression, but the impact of digital economy development might differ by a country's level of development, institutional context, or economic structure. Future research could examine heterogeneous effects – for instance, are the benefits of internet expansion for youth employment larger in developing countries (where it can leapfrog traditional barriers) or in developed countries (where it complements high-tech industries)? Do factors like governance quality or business climate condition the effectiveness of ICT education in reducing unemployment? Additionally, as the digital economy is a broad concept, one could extend the analysis to other facets such as the role of e-government services, mobile phone penetration, or the rise of platform/gig work in influencing youth labour outcomes. Investigating youth

underemployment or job quality in the digital era would also be a valuable extension, since mere employment counts do not capture if young workers are in stable, decent jobs.

Conclusions

This study examined the relationship between the digital economy and youth unemployment in the European Union, finding clear evidence that digital development and youth labour market outcomes are closely intertwined. Our analysis yielded two key insights. First, digitalisation appears to be an important avenue for reducing youth unemployment: countries and years with greater internet access, higher digital skill prevalence among young workers, and more robust digital training tend to experience lower rates of youth joblessness, all else equal. This was demonstrated by our panel regression results, which showed significant negative effects of household connectivity and ICT-oriented human capital on youth unemployment. In plain terms, young people fare better in the job market when they are equipped with digital skills and when they can leverage ubiquitous internet access to seek and perform work. However, a second crucial finding is that digital factors operate in tandem with broader economic conditions. Strong GDP growth and healthy macroeconomic environments remain indispensable for translating digital potential into actual jobs for youth. Our cluster analysis highlighted this interplay vividly: high-performing countries (with low youth unemployment) combine extensive digital infrastructure and skilled youth with favourable economic conditions, whereas countries with persistently high youth unemployment tend to suffer from structural economic weaknesses even if their digital metrics are moderately good. Cluster 1 countries should focus on advancing digital specialisation to meet future labour demands. Cluster 2 needs to improve infrastructure and connect its skilled youth to industry. Cluster 3 must maintain its current balance by continuing to invest in education and innovation. Cluster 4 requires deeper economic reforms to translate digital potential into real job opportunities. Across all clusters, it is evident that digital readiness must be complemented by inclusive policies and robust economic conditions to effectively reduce youth unemployment.

Overall, the empirical findings confirm Hypothesis 1 and Hypothesis 3, while Hypothesis 2 receives partial support. This suggests that digital infrastructure and macroeconomic conditions play the most consistent role in reducing youth unemployment, whereas the contribution of education-related digital indicators appears more nuanced.

These conclusions carry several implications. Importantly, they reinforce that advancing the digital economy should be a central component of strategies to tackle youth unemployment in the EU. Enhancing connectivity and digital skills among the youth can directly improve their employability and open up new employment

avenues, from It jobs to digitally enabled entrepreneurial ventures. At the same time, our findings stress that digital initiatives should complement, not substitute, sound macroeconomic management and job-creation policies. A holistic approach is needed: investments in broadband, education, and ICT training will have maximal impact when coordinated with efforts to stimulate economic growth and remove labour market barriers for young workers. In terms of novelty, our study contributes to the literature by integrating a cross-country panel analysis with a clustering perspective, using up-to-date data through 2023. This allowed us not only to quantify the average effects of digitalisation on youth unemployment but also to identify distinct country groupings and developmental pathways within the EU.

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REFERENCES

Arntz, M., Gregory, T., & Zierahn, U. (2016). *The risk of automation for jobs in OECD countries: A comparative analysis* (Working Papers No. 189). OECD Social, Employment and Migration. OECD Publishing. https://doi.org/10.1787/5jlz9h56dvq7-en

Artyukhov, A., Artyukhova, N., Navolokina, A., Brych, V., Koziuk, V., & Kolinets, L. (2025). Immersive university: Step beyond the metaverse and education. In *2025 15th International Conference on Advanced Computer Information Technologies (ACIT)* (pp. 1007–1012). IEEE. https://doi.org/10.1109/ACIT65614.2025.11185660

Barna, C., & Epure, M. (2020). Analyzing youth unemployment and digital literacy skills in Romania in the context of the current digital transformation. *Romanian Statistical Review, 20*(2), 17–25. https://ideas.repec.org/a/rse/wpaper/v20y2020i2p17-25.html

Başol, O., Sevgi, H., & Yalçın, E. C. (2023). The effect of digitalization on youth unemployment for EU countries: Treat or threat? *Sustainability, 15*(14), Article 11080. https://doi.org/10.3390/su151411080

Buzalova, S., Vansac, P., Tomanek, P., & Rottermund, J. (2024). Mental health and work-life balance among workers in social services. *Clinical Social Work and Health Intervention, 15(5)*, 5–15. https://doi.org/10.22359/cswhi_15_5_02

Crisan, G.-A., Popescu, M. E., Militaru, E., & Cristescu, A. (2023). EU diversity in terms of digitalization on the labor market in the post-COVID-19 context. *Economies*, *11*(12), Article 293. https://doi.org/10.3390/economies11120293

Dervishaj, A., & Presi, O. (2024). Digital creative methods contribute to teaching through collaborative schemes. *Journal of Education Culture and Society*, *15*(1), 453-471. https://doi.org/10.15503/jecs2024.1.453.471

Enciso-Santocildes, M., Echaniz-Barrondo, A., & Gómez-Urquijo, L. (2021). Social innovation and employment in the digital age: The case of the connect employment shuttles in Spain. *International Journal of Innovation Studies, 5*(4)*,* 175–189. https://doi.org/10.1016/j.ijis.2021.11.001

European Commission. (2021). *Digital education action plan (2021–2027)*. https://education.ec.europa.eu/focus-topics/digital-education/action-plan

European Commission. (2023). *Europe's digital decade: Digital targets for 2030.* https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en

Frey, C. B., & Osborne, M. A. (2017). The future of employment: How susceptible are jobs to computerisation? *Technological Forecasting and Social Change, 114*, 254–280. https://doi.org/10.1016/j.techfore.2016.08.019

Hussain, A., Batool, I., Akbar, M., & Nazir, M. (2021). Is ICT an enduring driver of economic growth? Evidence from South Asian economies. *Telecommunications Policy*, *45*(8), Article 102202. https://doi.org/10.1016/j.telpol.2021.102202

Idris, M., & Maikomo, J. M. (2024). Impact of digital economy on youth unemployment in Nigeria. *KASU Journal of Economics and Development Studies, 10*(2), 141–158.

International Labour Organization (ILO). (2020). *Global employment trends for youth 2020: Africa.* https://www.ilo.org/sites/default/files/wcmsp5/groups/public/@dgreports/@dcomm/@publ/documents/publication/wcms_737648.pdf

Jeyaraj, J. J., Chong, S. C., Chin, M. Y., & Foo, L. P. (2024). Mitigating youth unemployment through gig employment: A System GMM analysis. *Pakistan Journal of Life and Social Sciences*, *22*(2), 2173–2185. https://doi.org/10.57239/PJLSS-2024-22.2.00156

Kobylarek, A. (2024). Types of knowledge in post-scientistic society. *Journal of Education Culture and Society*, *15*(2), 7-16. https://doi.org/10.15503/jecs2024.2.7.16

Kondrla, P., Makan, F., Kralik, R., & Guttesen, K. (2024). The role of spiritual values in social work: The context of sustainability. *Clinical Social Work and Health Intervention*, *15*(6), 120-129. https://doi.org/10.22359/cswhi_15_6_10

Lederman, D., & Zouaidi, M. (2022). Incidence of the digital economy and frictional unemployment: International evidence. *Applied Economics*, *54*(51), 5873–5888. https://doi.org/10.1080/00036846.2022.2054927

Lima, Y., Barbosa, C. E., Salazar dos Santos, H., & de Souza, J. M. (2021). Understanding technological unemployment: A review of causes, consequences, and solutions. *Societies, 11*(2), Article 50. https://doi.org/10.3390/soc11020050

Mamat, A., Mohamad, F., Mohamed, M. A., Rawi, N., & Awang, M. I. (2018). Silhouette index for determining optimal k-means clustering on images in different color models. International *Journal of Engineering & Technology*, *7*(2.14*),* 105–109. https://doi.org/10.14419/ijet.v7i2.14.11464

Mossberger, K., LaCombe, S., & Tolbert, C. J. (2021). A new measure of digital economic activity and its impact on local opportunity. *Telecommunications Policy*, *46*, Article 102231. https://doi.org/10.1016/j.telpol.2021.102231

Nouffeussie, A. C. N., Meka'a, C. B., Noufelie, R., & Balguesam, B. N. (2024). Use of ICT: What effect on youth access to employment in Cameroon? *Heliyon*, *10*(21), Article e39967. https://doi.org/10.1016/j.heliyon.2024.e39967

Organisation for Economic Co-operation and Development (OECD). (2021). *Investment promotion and the digital economy* (Policy Paper, No. 54). OECD Business and Finance. OECD Publishing. https://doi.org/10.1787/5c840788-en

Ogbonna, A. E., Adediran, I. A., Oloko, T. F., & Others. (2023). Information and communication technology (ICT) and youth unemployment in Africa. *Quality & Quantity*, *57*, 5055–5077. https://doi.org/10.1007/s11135-022-01600-9

Ouko, K. O., Ogola, J. R. O., Ng'on'ga, C. A., & Wairimu, J. R. (2022). Youth involvement in agripreneurship as nexus for poverty reduction and rural employment in Kenya. *Cogent Social Sciences, 8(1)*, Article 2078527. https://doi.org/10.1080/23311886.2022.2078527

Oyedemi, T. D., & Choung, M. (2020). Digital inequality and youth unemployment. *Communicatio*, *46(3)*, 68–86. https://doi.org/10.1080/02500167.2020.1821738

Petrescu, C., Voicu, B., Heinz-Fischer, C., & Others. (2024). Conceiving of and politically responding to NEETs in Europe: A scoping review. *Humanities and Social Sciences Communications, 11*, Article 226. https://doi.org/10.1057/s41599-024-02713-2

Petrikovičová, L., Petrikovič, J., Kurilenko, V., Taraj, M., Kholov, S., & Azizi, M. (2023). Impact of the global COVID-19 pandemic on the Slovak economy (tourism and education). *Journal of Education Culture and Society*, *14*(2), 468-483. https://doi.org/10.15503/jecs2023.2.468.483

Popovych, V., Serbii, S., Popovych, Y., Taran, V., & Balukhtina, O. (2024). Refugee crisis in the European Union countries: Problems and consequences. *Clinical Social Work and Health Intervention, 15*(4), 98–106. https://doi.org/10.22359/cswhi_15_4_12

Qu, Y., & Fan, S. (2024). Is there a "machine substitution"? How does the digital economy reshape the employment structure in emerging market countries? *Economic Systems, 48*(4), Article 101237. https://doi.org/10.1016/j.ecosys.2024.101237

Shevchenko, I., Zavadskykh, H., Ptashchenko, O., Zvonar, V., & Vishka, I. (2023). The application of digitization in the economy as a promising direction in the growth of human capital. *Economic Affairs, 68*(01s), 345–352. https://doi.org/10.46852/0424-2513.1s.2023.37

Tee, P. K., Wong, L. C., Dada, M., Song, B. L., & Ng, C. P. (2024). Demand for digital skills, skill gaps and graduate employability: Evidence from employers in Malaysia. *F1000Research, 13*, Article 389. https://doi.org/10.12688/f1000research.148514.1

Tunji-Olayeni, P. F., Osabuohien, E. S., Yabkwa, I., & Onabote, A. A. (2021). Youth employment creation as an inclusive solution for sustainable development: Lessons from the 'Double You Digital Skills Initiative' in Nigeria. *IOP Conference Series: Earth and Environmental Science, 665*(1), Article 012019. https://doi.org/10.1088/1755-1315/665/1/012019

Wang, J., Tian, Z., & Sun, Y. (2024). Digital economy, employment structure and labor share. *Sustainability*, *16*(21), Article 9584. https://doi.org/10.3390/su16219584

Wu, R. (2023). Impacts of digital economic transformation on youth employment: Empirical evidence from China. *Advances in Economics, Management and Political Sciences*, *37*, 161-169. https://doi.org/10.54254/2754-1169/37/20231859

Appendix A

Table A1

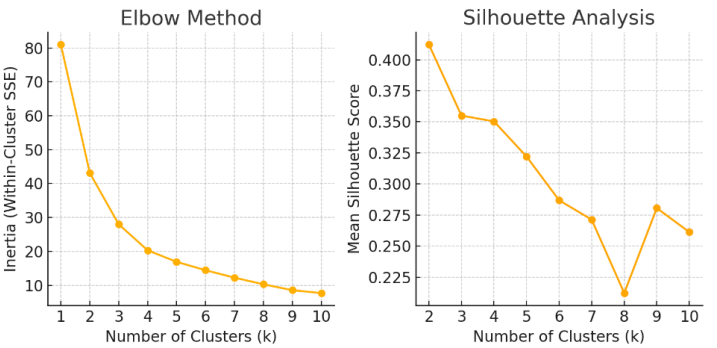
List of Variables

Variable		Indicator Description	Role in Model
Youth Unemployment Rate (%)	Y	% of active population aged 15-24 unemployed (Eurostat, 2025h)	*Dependent Variable*
Household Internet Access (%)	X1	% of households with internet access, (Eurostat, 2025e)	Predictor: Digital Infrastructure
Enterprises Providing ICT Training (%)	X2	% of enterprises providing ICT skill training (Eurostat, 2025d)	Predictor: Digital Skill Development
Employed Persons with ICT Education (%)	X3	% of youth aged 15-34 with ICT education employed, (Eurostat, 2025c)	Predictor: ICT Education Impact
Tertiary Education Attainment (%)	X4	% of youth aged 15-29 with tertiary education, (Eurostat, 2025g)	Predictor: Education Attainment
Employed ICT Specialists (%)	X5	% of ICT specialists in total employment, (Eurostat, 2025b)	Predictor: Digital Workforce
Real GDP Growth Rate (%)	X6	Annual GDP growth rate, (Eurostat, 2025f)	Control Variable: Economic Performance
Average Full-Time Adjusted Salary (EUR)	X7	Average full-time salary per employee, (Eurostat, 2025a)	Control Variable: Wage Impact

Source. Own research.

Figure A1

Determining the Optimal Number of Clusters



Source. Own research.

Table A2

Relationship between the regression and clustering datasets

Analysis	Unit of analysis	Countries	Period	Number of observations	Variables used
OLS regression	Country-year observations	27 EU countries	2013–2023	297	Youth unemployment, household internet access, ICT education, tertiary education attainment, real GDP growth
K-means clustering	Country-level averages	27 EU countries	2013–2023 averages	27	Household internet access, ICT education, youth unemployment

Source. Own research.

Table A3

Descriptive statistics for variables used in the OLS regression, EU-27, 2013–2023

	X1	X2	X3	X4	X5	X6	X7	Y
Mean	85,4437	21,562	69,988	20,464	4,1542	2,4915	29318,4	19,4407
Standard Error	0,5421	0,4685	0,57062	0,3295	0,0809	0,21986	965,53	0,58179
Median	87,71	21,84	71,1	19,6	3,9	2,4	24294	17,3
Mode	74,35	23,72	77,1	14,6	3,6	2,3	45727	20,5

	X1	X2	X3	X4	X5	X6	X7	Y
Standard Deviation	9,3431	8,0754	9,8340	5,67987	1,3943	3,7890	16639,68	10,026
Sample Variance	87,293	65,2132	96,708	32,2609	1,9442	14,3571	2,77E+08	100,530
Kurtosis	0,46972	-0,6374	-0,0504	-0,2990	0,3973	5,22469	-0,57243	2,0461
Skewness	-0,9332	0,0123	-0,436	0,42327	0,7238	0,43043	0,637065	1,3875
Range	45,47	35,93	52,7	26,5	7,1	35,5	75360	53,6
Minimum	53,71	4,43	37,8	9,2	1,6	-10,9	5704	5,6
Maximum	99,18	40,36	90,5	35,7	8,7	24,6	81064	59,2
Sum	25376,78	6404,06	20786,5	6077,9	1233,8	740	8707569	5773,9
Count	297	297	297	297	297	297	297	297
Largest(1)	99,18	40,36	90,5	35,7	8,7	24,6	81064	59,2

Source. Own research.

Appendix B

Table B1

Panel Data Results

	Coeffi-cients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	86,46881	8,26828	10,4579	6,41E-22	70,19512	102,7425
X1	-0,67105	0,07874	-8,52237	8,8E-16	-0,82603	-0,51607
X2	-0,06789	0,07951	-0,85385	0,393894	-0,22438	0,088602
X3	-0,14222	0,066413	-2,14152	0,033069	-0,27294	-0,01151
X4	0,176052	0,091471	1,924671	0,055252	-0,00398	0,356085
X5	-0,77696	0,596417	-1,30271	0,193711	-1,95083	0,396914
X6	-0,42409	0,127297	-3,33151	0,000976	-0,67464	-0,17354
X7	8,21E-05	4,97E-05	1,651853	0,099651	-1,6E-05	0,00018

Source. Own research.

Table B2

ANOVA Results

ANOVA					
	df	SS	MS	F	Significance F
Regression	4	10558,35	2639,589	40,14658	8,63E-27
Residual	292	19198,64	65,74877		
Total	296	29757			

Source. Own research.

Table B3

Country-level averaged indicators, EU-27, 2013–2023

Country	X1	X3	Y	Years Observed
Austria	88.2154	62.436363	10.6181818	11
Belgium	87.65363	71.3545454	18.7818181	11
Bulgaria	71.43272	72.5363636	18.50909090	11
Croatia	79.24181	82.827272	28.7111213	11
Cyprus	82.41727	70.9636363	24.44545454	11
Czechia	84.495454	77.04545454	9.95454545	11
Denmark	94.514545	59.80909090	11.90909090	11
Estonia	88.43122	75.827272723	15.30909090	11
Finland	93.7218181	47.38181818	18.8727277	11
France	88.0418181	67.2909090	22.3111122	11
Germany	92.0436363	62.99090909	7.15454545	11
Greece	74.81121	73.3999999	42.3181818	11
Hungary	82.9072727	72.47272727	14.3181818	11
Ireland	89.099090	57.01818181	16.2727272	11
Italy	82.5345454	74.74545454	32.9636363	11
Latvia	82.6636363	73.38181818	15.9818181	11
Lithuania	77.3236363	77.9818181	15.26363636	11
Luxembourg	96.2463636	63.43636363	17.9454545	11
Malta	85.7809090	82.68181818	10.58181818	11
Netherlands	97.3027272	64.06363636	10.55454545	11
Poland	84.10363636	72.918181818	15.61818181	11
Portugal	77.9809090	75.990909090	25.52727272	11
Romania	77.8236363	81.236363636	24.045454545	11
Slovakia	83.41909090	80.381818181	22.781818181	11
Slovenia	85.017272	68.77272	13.56363636	11
Spain	86.343636	64.33636	39.8636363636	11
Sweden	93.41545454	56.4	20.7454545454	11

Source. Own research.

Table B4

Descriptive statistics for variables used in the K-means cluster analysis, EU-27, 2013–2023 averages

	X1	X3	Y
N	27	27	27

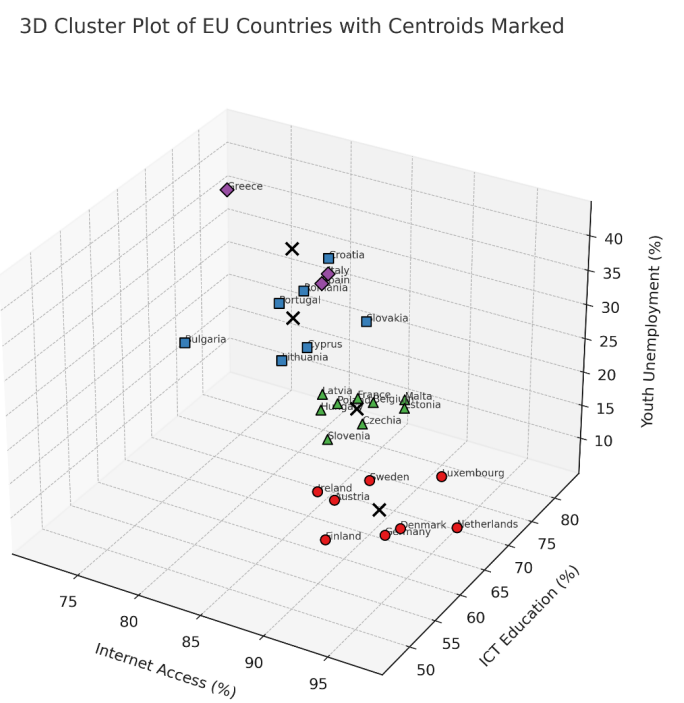
	X1	X3	Y
Mean	85.444	69.988	19.441
Std. Dev.	6.575	8.785	8.731
Min	71.433	47.382	7.155
25%	82.476	63.750	13.941
Median	85.017	72.473	17.945
75%	88.765	75.909	23.414
Max	97.303	82.827	42.318
Skewness	-0.077	-0.645	1.150
Kurtosis	-0.396	0.159	1.180

Source. Own research.

Appendix C

Figure C1

3D Cluster Plot of EU Countries



Source. Own research.

REFERENCES A

Eurostat. (2025a). *Average full time adjusted salary per employee*. European Commission. https://doi.org/10.2908/nama_10_fte

Eurostat. (2025b). *Employed information and communications technology (ICT) specialists*. European Commission. https://doi.org/10.2908/isoc_sks_itspt

Eurostat. (2025c). *Employed persons with information and communications technology (ICT) education by age*. European Commission. https://doi.org/10.2908/isoc_ski_itage

Eurostat. (2025d). *Enterprises that provided training to develop/upgrade ICT skills of their personnel by NACE Rev. 2 activity*. European Commission. https://doi.org/10.2908/isoc_ske_ittn2

Eurostat. (2025e). *Households: Level of internet access*. European Commission. https://doi.org/10.2908/isoc_ci_in_h

Eurostat. (2025f). *Real GDP growth rate: Volume*. European Commission. https://doi.org/10.2908/tec00115

Eurostat. (2025g). *Young people by educational attainment level, sex and age*. European Commission. https://doi.org/10.2908/yth_demo_040

Eurostat. (2025h). *Youth unemployment rate by sex, age and country of birth*. European Commission. https://doi.org/10.2908/yth_empl_100