DIGITALIZATION STRUCTURALLY CHANGES THE LABOUR MARKET: A COMPARATIVE ANALYSIS IN EU COUNTRIES

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Abstract

The process of automation, implementation, and expansion of information and communication technologies (ICT) in EU countries has had a strong impact on the labour market, which has undergone significant transformation, as advanced technologies both create and eliminate numerous jobs. Consequently, the number, structure, and quality of jobs available on the labour market have changed considerably, together with the skills and competencies required to fill them. At the same time, the education and vocational training systems must adapt to these new competency requirements, which increasingly emphasize specific human and social skills.

Under these circumstances, this study analyses the expansion of the digitalization process in EU countries during the period 2010-2024 by examining several key indicators: GDP per capita, employment rate, unemployment rate, and the number of employed ICT specialists. We subsequently analysed the evolution of the online labour demand market on a quarterly basis during the period 2019-2025 in order to observe changes in the occupational distribution of labour demand.

The study reveals different levels of digitalization and automation across EU countries by the end of 2024, as well as different patterns in the evolution of occupational labour demand during the analysed period. The conclusions of the analysis may assist decision-makers in

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EU countries in shaping policies aimed at stimulating adaptation and flexibility within higher education and vocational training systems, as well as investments in research and development and occupational health and safety activities.

Keywords: digitalization, digital skills, ICT specialists

JEL Classification: O1, O150, C12

1. Introduction

Digitalization and the expansion of information and communication technologies (ICT) across all areas of economic, social, and cultural life have become key objectives on the agendas of several international institutions, including the World Bank Group, the World Economic Forum, the International Labour Organization, the European Commission, the European Parliament, and the OECD. These institutions have supervised, regulated, monitored, and encouraged the so-called digital revolution.

The process of automation and the implementation and expansion of ICT in the economies and societies of EU Member States have been strongly supported by the European Commission, national governments, specialized institutions, research institutes, and academia, all of which have demonstrated the major impact of these technologies on the lives of European citizens.

The expansion of digitalization, the increasing use of robotics, and the gradual transition toward Artificial Intelligence (AI) have been continuously analysed by the OECD [1][2], monitored by the ILO [3][4], the European Commission [5][6][7], and the European Parliament [10]. These institutions have highlighted the risks associated with automation, robotics, and AI regarding the loss of traditional jobs, but especially the emergence of new requirements in terms of competencies and skills necessary for future employment opportunities.

Similarly, the World Economic Forum has repeatedly drawn attention to the future risks associated with job displacement caused by automation and computerization, as well as the resulting impact on employment and unemployment within modern societies [11][12].

These developments have profoundly affected labour markets. Advanced technologies simultaneously create and eliminate jobs. Employees increasingly face the disappearance of automated positions and substantial changes in the digital and communication skills required for their current occupations. At the same time, employers have vacancies requiring digital competencies ranging from basic to highly advanced levels, which necessitate either higher education qualifications or specialized training programmes.

As a result, the number, structure, and quality of jobs available on the labour market have changed significantly [13], together with the competencies and skills required to perform them, as well as the processes of lifelong learning and continuous adaptation [14][15].

In order to maintain equilibrium in labour markets, substantial efforts are being made to ensure that the workforce adapts to new technologies and is prepared to cope with the growing automation of activities. These efforts involve employers, employees, unemployed individuals, governments, public administrations, and local authorities, all of whom contribute through policies adapted to their specific contexts. Such measures are continuously required to address the opportunities and challenges generated by technological change.

In response to labour market requirements and their own operational needs, an increasing number of companies have adapted by organizing specialized ICT training programmes both for their own employees and for other interested workers. The Managing Director of the International Monetary Fund (IMF) has emphasized that the impact of digitalization on labour markets is substantially stronger in advanced economies (approximately 60%) than in developing economies (approximately 30%), which may inevitably increase global inequality [16].

2. Previous Literature in the Field

Concerned about the risk of job loss and uncertainty regarding future employment opportunities, both employees and employers have increasingly focused on understanding labour market transformations. Recent research has examined changes generated by the automation and computerization of entire work, learning, and decision-making processes, including the potential deepening of social inequalities and, conversely, the reduction of poverty among employed populations [17].

It is well known that labour market conditions can be assessed through rigorous indicators such as the employment rate, unemployment rate, GDP per capita, and the degree of automation and digitalization, often measured by the number of employed ICT specialists. Accordingly, we reviewed studies investigating the relationship between the digitalization of activities and services, progressive robotization, employment, unemployment, and economic development both within the European Union and beyond.

The business sector has increasingly requested studies capable of guiding organizations during a period characterized by the implementation of innovative and ICT-based technologies, which generate not only economic efficiency but also significant uncertainty regarding the content of emerging occupations and new job roles.

Several studies [18][19] have identified occupations likely to disappear as well as a growing range of new jobs increasingly demanded on the labour market. These positions are primarily related to software application development, big data analytics, cybersecurity, green energy engineering, and ICT specializations in healthcare, manufacturing, education, and social services.

Researchers have also analysed and synthesized the competency requirements associated with these emerging occupations, making them widely available through their studies [20][19][21][22][23][24].

Other scholars have investigated the correlation between economic development and the number (or percentage) of employed ICT specialists, as well as the direct impact of digitalization on employment rates, unemployment, and wage levels across countries [25][26][24][27][28][29][30]. Research by Bachman, within a study on 16 European countries between 2000-2017, [31] has shown that the effects of robotics are felt most strongly by workers performing predominantly manual and repetitive tasks and less intensely by workers engaged in cognitive activities. Furthermore, in less developed countries, employment has increased and unemployment caused by technological displacement has declined due to the creation of new jobs and the implementation of policies encouraging labour mobility among specialized workers.

A study conducted for the OECD Social [32], Employment and Migration programme examined 21 OECD countries and assessed the risk of job loss resulting from the extensive adoption of ICT technologies. The findings suggested that only 9% of jobs were highly automatable and therefore exposed to a substantial risk of total or partial elimination, whereas several traditional occupations identified in other studies have already disappeared or are currently declining [19].

This conclusion significantly reduced concerns regarding large-scale job losses caused by digitalization, robotization, and computerization. Moreover, the study demonstrated that this percentage varies among countries depending on their level of development, investment in research and innovation, ICT expenditure, educational attainment of ICT specialists, and overall social and technological progress.

A substantial body of research has also focused on the competencies required by new occupations strongly influenced by automation and computerization. The introduction of new technologies may lead to the disappearance or significant transformation of existing job tasks, while simultaneously generating concerns among employees and their families regarding income security, unemployment risks, and the need to adapt through acquiring new knowledge, competencies, and skills required by emerging working conditions [33][34][35][36].

3. Preliminary Data Analysis

Consistent with a large part of the literature reviewed, our analysis considered data on GDP per capita, employed ICT specialists, employment rate, and unemployment rate for the 27 EU Member States during the period 2010-2024. The data were obtained from the Eurostat database [75] and subsequently processed and synthesized by the authors.

It should be noted that EU Member States exhibit different levels of economic development. Consequently, the expansion and intensification of digitalization, automation, and

robotization processes differ substantially among countries, which may further widen existing development gaps.

An analysis of the GDP per capita (GDPpc) indicator for the 27 EU Member States, expressed in euro per capita (Table 1), reveals a continuous increase over the fifteen-year period under review. This reflects both economic growth and improvements in living standards throughout the European Union.

However, a closer examination shows that several countries started from very low GDP per capita levels in 2010, considerably below the EU average. Although these countries experienced significant growth rates, their GDP per capita remained relatively low compared with the EU average in 2024.

This is particularly evident in the cases of Bulgaria and Romania, whose GDP per capita increased from €7,060 and €8,050 respectively in 2010 to €11,300 and €13,130 in 2024. Although the percentage increases were substantial (approximately 60% and 63.1%, respectively), both countries remained well below the EU average of €33,550 in 2024.

A similar situation can be observed in Hungary, Latvia, Lithuania, and Poland, which, despite recording notable economic progress, also remained below the EU average by 2024. During the analysed period, these countries implemented intensive digitalization programmes supported by substantial ICT investments, which significantly contributed to economic growth, as demonstrated by previous research [37][38][39].

Conversely, several countries began the period, in 2010, with GDP per capita levels significantly above the EU average and continued to grow steadily while maintaining their advantageous position even in 2024. These include the highly developed EU economies of: Denmark, Germany, Ireland, Netherlands, Austria, Finland, Sweden, Belgium, France and Italy.

A special case is represented by Luxembourg, whose GDP per capita reached €103,430 in 2010 - approximately 3.6 times the EU average. Although it experienced slight fluctuations thereafter, Luxembourg maintained a GDP per capita level roughly three times higher than the EU average throughout the analysed period.

Country / Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
European Union-27	28,52	29,03	28,76	28,72	29,16	29,78	30,29	31,09	31,67	32,20	30,44	32,36	33,26	33,28	33,55
Belgium	39,42	39,67	39,51	39,44	39,96	40,31	40,59	41,03	41,61	42,40	40,19	42,51	43,96	44,12	44,30
Bulgaria	7,06	7,39	7,53	7,60	7,76	8,13	8,48	8,83	9,18	9,67	9,45	10,25	10,74	10,97	11,30
Czechia	17,77	18,12	17,97	17,97	18,37	19,27	19,76	20,76	21,32	22,05	20,98	21,83	21,91	21,68	21,91
Denmark	49,01	49,44	49,26	49,75	50,11	50,81	51,95	53,20	53,92	54,63	53,54	56,78	56,53	56,47	58,16
Germany	38,42	39,87	39,98	40,02	40,72	41,04	41,64	42,61	42,96	43,29	41,48	42,99	43,26	42,78	42,58
Estonia	15,38	16,59	17,26	17,63	18,28	18,65	19,19	20,27	20,97	21,65	20,96	22,44	22,43	21,21	21,02
Ireland	43,99	44,51	44,15	44,89	48,77	60,21	60,22	65,37	69,39	71,72	75,82	87,16	91,76	87,81	88,60

Greece	19,30	17,42	16,05	15,80	16,03	16,10	16,16	16,43	16,81	17,21	15,66	17,11	18,20	18,67	19,13
Spain	24,51	24,26	23,56	23,31	23,73	24,72	25,42	26,11	26,62	26,93	23,85	25,44	26,77	27,15	27,74
France	34,31	34,99	34,88	34,99	35,15	35,37	35,54	36,14	36,57	37,16	34,28	36,47	37,32	37,76	38,11
Croatia	11,44	11,47	11,25	11,27	11,26	11,60	12,10	12,63	13,12	13,87	12,84	14,56	15,64	16,06	16,71
Italy	30,44	30,55	29,51	28,92	28,91	29,21	29,63	30,16	30,47	30,68	28,10	30,76	32,31	32,56	32,81
Cyprus	23,89	23,39	22,28	20,83	20,49	21,14	22,41	23,50	24,69	25,79	24,63	27,03	28,44	28,67	29,19
Latvia	10,84	11,38	12,36	12,75	13,14	13,75	14,23	14,85	15,61	15,82	15,37	16,58	16,87	17,39	17,51
Lithuania	11,16	12,14	12,83	13,48	14,10	14,63	15,20	16,09	17,03	17,87	17,89	19,04	19,36	19,16	19,58
Luxembourg	103,43	102,11	101,44	102,01	102,24	102,53	104,92	104,02	103,64	104,31	102,19	107,57	104,10	101,45	100,88
Hungary	11,06	11,30	11,22	11,49	12,04	12,53	12,88	13,46	14,24	14,98	14,37	15,47	16,17	16,06	16,19
Malta	20,73	20,85	21,53	22,59	23,83	25,50	25,95	28,51	29,49	29,46	27,89	31,41	31,91	32,74	33,61
Netherlands	44,40	44,98	44,37	44,23	44,78	45,53	46,38	47,39	48,18	48,97	46,81	49,49	51,48	50,66	50,88
Austria	42,28	43,37	43,45	43,08	43,07	43,20	43,55	44,26	45,14	45,73	42,65	44,52	46,35	45,51	44,83
Poland	10,15	10,68	10,84	10,93	11,36	11,87	12,24	12,87	13,68	14,31	14,31	15,38	15,84	15,95	16,47
Portugal	19,44	19,11	18,41	18,33	18,56	18,92	19,35	20,02	20,62	21,15	19,36	20,39	21,69	22,02	22,23
Romania	8,05	8,46	8,66	8,71	9,10	9,43	9,76	10,62	11,33	11,83	11,46	12,19	12,73	13,03	13,13
Slovenia	19,92	20,01	19,39	19,21	19,72	20,17	20,77	21,83	22,72	23,33	22,23	24,04	24,66	25,05	25,38
Slovakia	14,10	14,54	14,75	14,83	15,22	16,00	16,28	16,73	17,38	17,76	17,27	18,32	18,35	18,75	19,13
Finland	41,66	42,46	41,62	41,02	40,65	40,70	41,64	42,91	43,36	43,91	42,74	43,80	44,01	43,43	43,04
Sweden	43,13	44,15	43,65	43,77	44,33	45,79	46,22	46,42	46,70	47,41	46,18	48,30	48,39	47,96	48,30

Tabel 1. DP per capita - Gross domestic product at market prices (euro per capita)
Source: Eurostat(2026), Database on Economic and Finance
(https://ec.europa.eu/eurostat/data/database)

A graphical representation of these data for 2024 can be seen in Fig. 1.

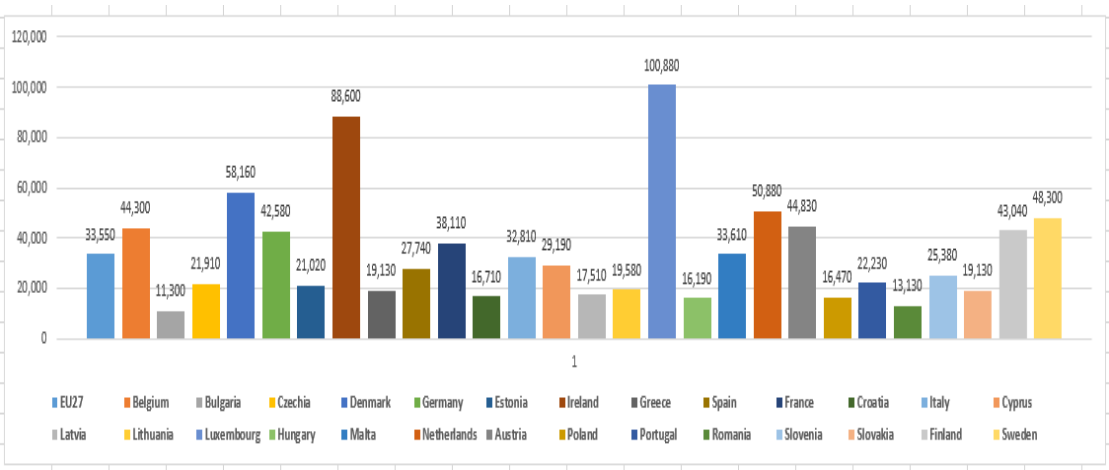

Fig.1 PIBL-Gross domestic product at market prices (euro per capita) in 2024

An analysis of the employment rate among the population aged 20-64 in EU countries during the period 2010-2024 shows that several less-developed Member States experienced substantial increases in employment alongside economic growth. Particularly significant increases were recorded in: Bulgaria, Estonia, Ireland, Latvia, Lithuania, Hungary, Malta, Poland and Romania. Employment growth in these countries ranged from approximately 19.8% to 30%, reaching nearly 37% in Malta.

This trend has also been confirmed by previous studies [40][41][42][43][44], which demonstrate that economic and social development generate new and diversified employment opportunities, thereby significantly increasing the employment rate of the working-age population.

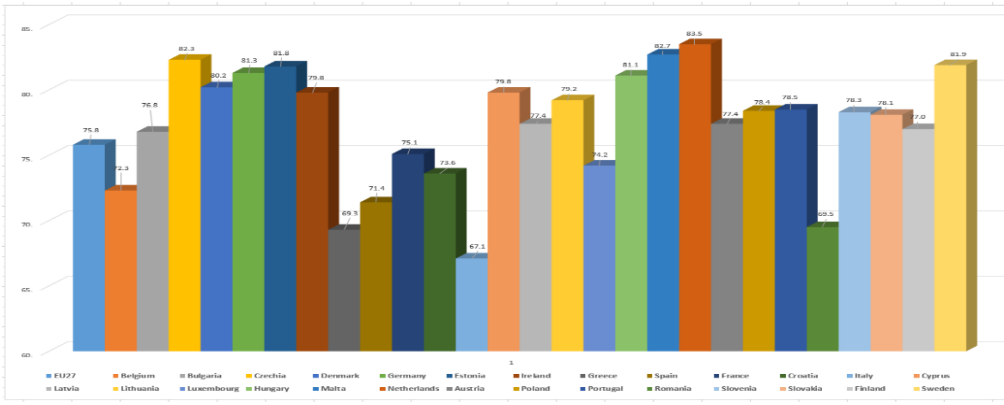

Fig 2. Total employment rate - From 20 to 64 years (Percentage of total population) in 2024

Similarly, unemployment rates across EU countries displayed substantial dynamics during the period 2010 - 2024.

Economic growth, reflected in increasing GDP per capita and rising employment rates, led to a considerable decline in unemployment in most European countries. The reductions observed generally ranged between 20% and 70%.

Nevertheless, a few countries recorded only limited decreases:

- Finland - decline of approximately 2-3%
- Sweden - decline of approximately 2-3%
- Austria - essentially unchanged

A particularly notable case is Luxembourg, where unemployment increased by approximately 45%, rising from 4.4% in 2010 to 6.4% in 2024.

These developments were influenced by the digitalization and automation of production, service, and work processes, which simultaneously eliminated certain jobs while creating new employment opportunities. In highly developed and highly digitalized economies, a slight increase in unemployment was observed as labour markets adjusted to these structural transformations [45][27][46].

The graphical representation of these values for 2024 can be seen in Fig. 3., below.

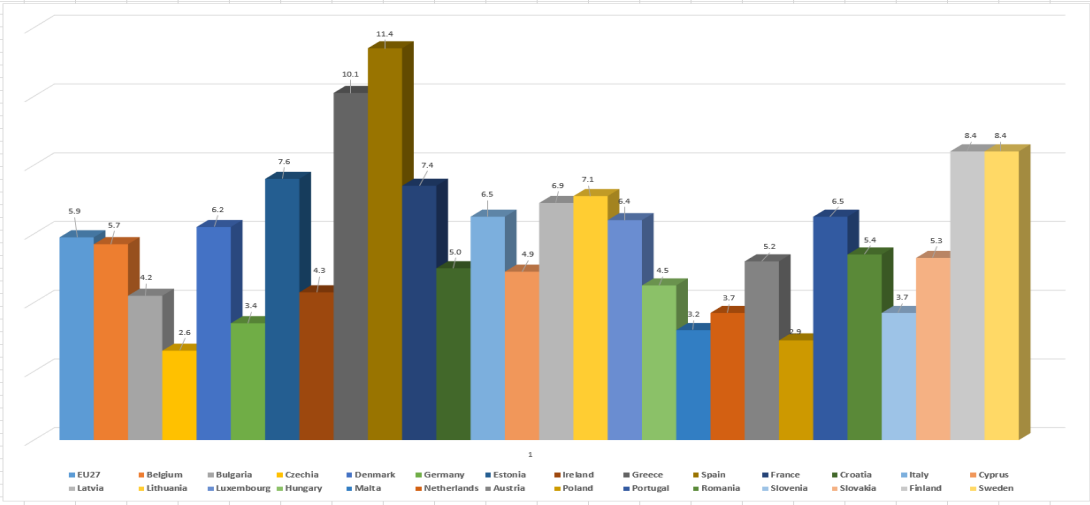

Fig. 3. Unemployment rate Total (Percentage of population in the labour force) in 2024

An analysis of the evolution of employed ICT specialists in EU countries between 2010 and 2024 reveals that only two countries experienced a decline:

- Czechia - approximately 3% decrease
- Greece - approximately 14% decrease

In all other EU countries, the number of ICT specialists increased significantly, demonstrating both the expansion and intensification of digitalization and automation across economic sectors.

For most countries, growth rates were broadly in line with the European average, ranging between 30% and 40%.
Particularly remarkable increases were recorded in:

- Estonia
- Netherlands
- Portugal

where growth exceeded 75%.
Even more striking increases were observed in:

- Croatia
- Lithuania

where the number of ICT specialists more than doubled.
These findings indicate that digital technologies and work-process automation were strongly supported in these countries and contributed significantly to economic growth. [37][47][48]

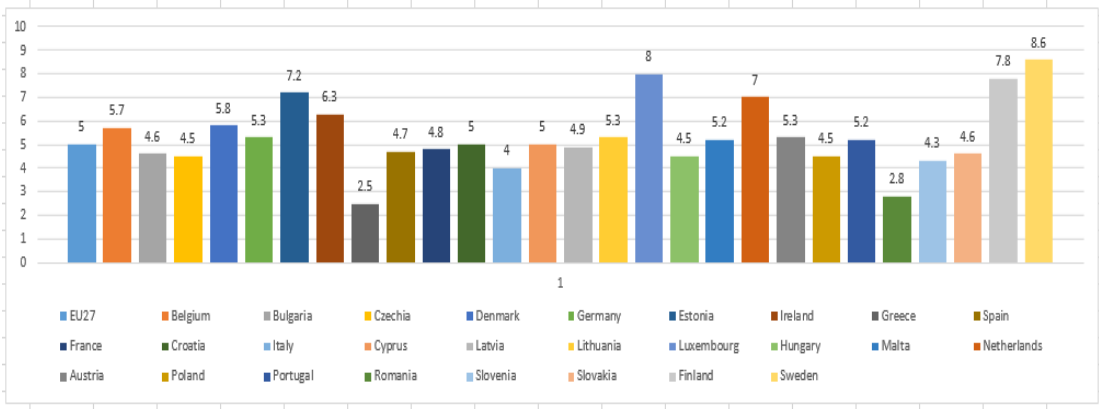

Fig. 4. Employed ICT specialists (Percentage of total employment) in 2024

4. Occupational Distribution of Demand for ICT Specialists in the Labour Market under Conditions of Digitalization of Work Processes

It has been observed that the informatization, automation, and robotization of production and/or services have, as an initial consequence, led to the complete or partial disappearance of certain occupations/professions and, consequently, of some jobs from the labour market. The immediate effect was a slight increase in unemployment, as advanced technologies, including those in the ICT domain, have contributed to the growth and diversification of production, and thus to rising incomes, which in turn enabled investments in new equipment and high-performance information systems. These developments inevitably fostered continuous growth, an increase in the number of new jobs, and investments in research, development, and innovation. Consequently, economic growth and efficiency were

achieved, along with higher wages for work tasks requiring higher education, as well as advanced competencies and skills. For all organizations, digital competencies have become mandatory, absolutely essential for fulfilling tasks in new jobs or occupations associated with emerging technologies.

If in 2021 approximately 9 million individuals were employed as ICT specialists in the EU, the European Union's objective is for this number to increase to around 20 million by 2030 [9]. Until then, concrete actions will be undertaken across EU countries to achieve the target whereby 80% of the EU population possesses at least basic digital skills, thereby facilitating adaptation to the new requirements of the labour market.

All these changes in the labour market have, however, required a series of local, central, and governmental policy measures designed to provide an appropriate organizational and legislative framework, capable of regulating and stimulating the actors involved (employers, employees, unemployed individuals, and the working-age population) to adapt dynamically to the new demands.

In the previous chapter, we examined the dynamics of four indicators directly related to the expansion of ICT and automation in the life of nations within EU countries over the period 2010 - 2024, and we produced a snapshot for the year 2024, when digitalization experienced significant development.

We now further analyse the quarterly data provided by Eurostat [7] regarding the occupational distribution (ISCO-08) of demand for ICT specialists in the labour market, as reflected in quarterly online job vacancy announcements for the period from the fourth quarter of 2019 to the second quarter of 2025 (Q4-2019, Q1-2020 … Q2-2025). It should be noted that, in Q4 2019, EU countries exhibited varying levels of informatization and automation, with developed and complex information systems, internet and computer networks of differing degrees of penetration, online commerce and payment systems, systems for organizing, storing, and protecting large volumes of data, cybersecurity systems, and Internet of Things (IoT) tools widely adopted across many sectors of activity, including renewable energy, transport, healthcare, and education.

The situation of these quarterly demands for ICT specialists on the online labor market, expressed as a percentage of total online labour demand, is as follows:

1. *Information and communications technology service managers.* This occupation exhibits slight fluctuations-either increases or decreases-which are certainly influenced by the greater or lesser availability of managers specialized in ICT technologies at the time these labour market demands are observed. Nevertheless, Czechia and Estonia stand out, showing a significantly higher demand for personnel in this category, accounting for approximately 40% of total online labour demand.
2. *Software and applications developers and analysts*. The demand in EU country markets for this category of ICT specialists-those responsible for the design,

programming, implementation, as well as the subsequent development and maintenance of complex information systems and applications that ensure the digital operation of production activities and/or services, along with the provision of technical assistance and support for their ongoing functioning and development-has been consistently high throughout the reported period, when expressed as a proportion of total online labour demand. This finding confirms the sustained interest in recruiting such ICT specialists, both within the business sector and at the governmental level, as there are also demands for specialists in local and central public administration, within key institutions underpinning the functioning of EU Member States. It is evident that, over the entire period analysed, this demand remained at an elevated level, reflecting the commitment of EU Member States to expanding and intensifying the process of digitalisation, both at the level of individual enterprises and organisations, and at national and European central levels. Notably, the Netherlands, Belgium, Austria, Poland, Finland, and Sweden stand out, exhibiting demand levels exceeding 60% of total online labour demand over the analysed period.

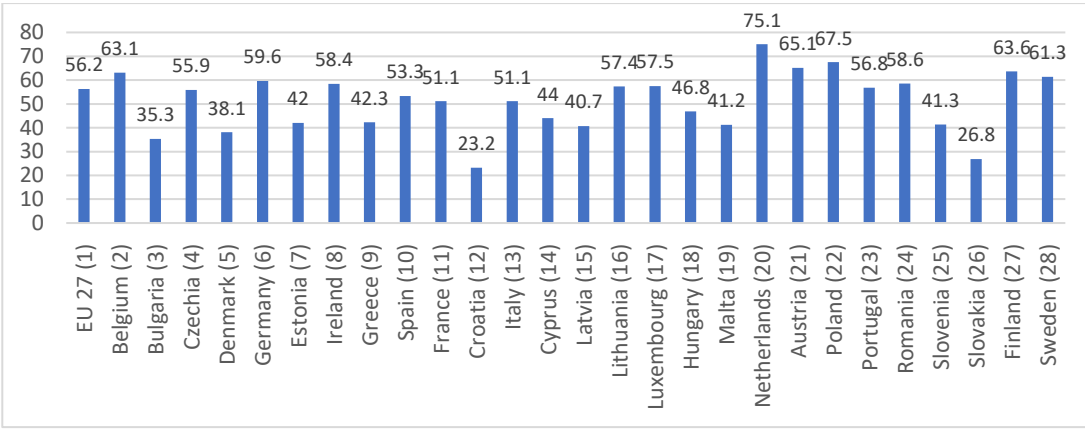

Fig. 5. The demand for ICT specialists: Software and Applications Developers and Analysts, in the second quarter of 2025.

3. *Database and network professionals*. As informatization expanded and increasingly complex and integrated information systems began to operate, specialists in data organisation, database management, and network functionality-ensuring the interconnectivity of all these networks and complex software products-became increasingly sought after on the labour market. In most EU countries, by 2020, the number of ICT specialists employed in this category was already substantial, their activity underpinning the ongoing expansion of digitalisation. For this reason, the demand for this type of ICT specialist over the analysed period (2020-2025) is comparatively lower as a proportion of total labour

demand, ranging between 7% and 12%. It is observed (Fig. 6) that in certain countries, demand for these specialists increased considerably in the second quarter of 2025 compared with the fourth quarter of 2019: Lithuania recorded an increase of 36%, Luxembourg 57%, Portugal 33%, Finland 31%, and Sweden 48%. This demand for specialists, similarly to the previously discussed category, confirms the continuous concern for recruiting professionals capable of advancing and intensifying the processes of informatization and automation across all work processes, as well as ensuring the connectivity of complex information systems, networks, and online working platforms across all sectors of activity.

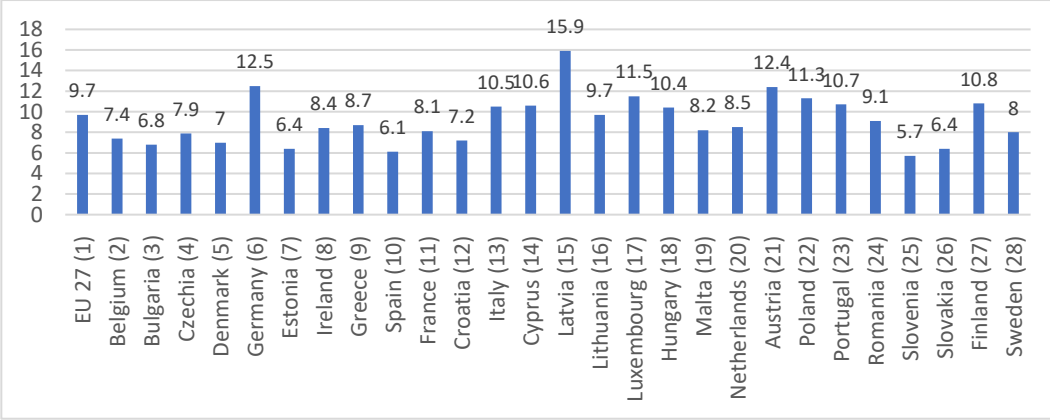

Fig.6. The demand for ICT specialists: Database and Network Professionals, in the second quarter of 2025.

4. *Information and communications technology operations and user support technicians.* This support staff-responsible for the maintenance and proper functioning of information systems and computer networks across all digitised, automated, or robotised activities-has consistently been a focus of employers throughout the analysed period, with relatively stable values from one quarter to another. However, online demand for these specialists, expressed as a percentage of total labour demand, increased in Ireland in the second quarter of 2025 compared with the fourth quarter of 2019 by 37%, in Slovakia by 62%, and in Croatia by a factor of 3.11. This demonstrates a sustained concern for the installation, implementation, and continuous maintenance of new hardware and software systems in operation, the number of which has grown steadily over time.
5. *Telecommunications and broadcasting technicians*. The demand for these specialists is relatively low, remaining between 1% and 3% of total online labour demand over the analysed period. Nevertheless, a notable increase can be observed beginning in the fourth quarter of 2021, with demand rising by 85% in France, by a factor of 4.2 in Finland, and by 5.7 times in Cyprus.

6. *Electronics and telecommunications installers and repairers.* The demand on the labour market for these specialists responsible for the maintenance of all electronic and telecommunications components has been relatively constant, albeit at a low level in terms of total labour demand, ranging between 0.1% and 1.8%. However, there are countries where investments in computer networks and their connectivity, in electronic equipment and necessary IoT devices, as well as in extensive online payment and e-commerce platforms, commenced later but increased significantly over the analysed period. This evolution consequently generated a very high demand for specialists in this category (Bulgaria - an increase of 7.7 times, Romania - 22 times, Belgium - 2.9 times, and Hungary - 2 times).
7. *Other information and communications technology specialists (OC2152, OC2153, OC2166, OC2356, OC2434, OC3114*)
   In EU countries, these specialists were demanded on the online labour market in varying proportions relative to total labour demand, ranging from 3% (Slovenia) to 45.2% (Bulgaria).

By correlating the number of ICT specialists employed during the period 2019-2024 with the online demand for such specialists, analysed by specific occupations, one may observe the concern of EU countries to meet the need for a specialised workforce possessing digital competencies. However, existing demand on the labour market for specialists with these competencies does not necessarily imply that such demand is fully satisfied. It should be noted that a high demand for specialists in a particular category, at a given moment in time in an EU country, does not necessarily indicate a significantly higher level of digitalisation compared with other countries; rather, it may be associated with the fact that that particular field of specialisation commenced later and progressed more slowly, thus generating a higher demand for specialised personnel at the time of analysis. Similarly, a lower proportion of demand for a certain type of specialist may be linked to the fact that the respective country initiated informatization earlier, trained specialists accordingly, and has most positions already filled with such professionals.

Enterprises, the business environment, and both local and central public administrations have undertaken significant efforts towards informatization through investments in information and communication technologies. They have supported the acquisition, installation, and maintenance of hardware and software components, created the jobs necessary for their efficient operation, and defined the competencies and skills required for their fulfilment. Digital infrastructure, advanced digital connectivity, the organisation of very large volumes of data, and the assurance of data protection and processing security-these extremely rapid developments have also led to the formulation of new and advanced digital competency requirements for these positions.

However, the advanced knowledge required in the fields of ICT, robotisation, and artificial intelligence is neither easily nor rapidly acquired. Consequently, there has been concern

regarding job losses in many sectors undergoing gradual informatization and automation, as well as concern among employers who encounter difficulties in finding specialised personnel with the required qualifications. Moreover, unemployed individuals and recent graduates face uncertainty in securing employment within a highly dynamic labour market, where competency and skills requirements are becoming increasingly stringent. Nevertheless, a range of specialised studies has demonstrated that digital evolution has generated a series of positive and beneficial effects on the workforce and on communities.

5. Labour market requirements concerning new competencies and skills in the context of the digitalisation of work processes

All transformations driven by the digitalisation process-across the business environment (production and/or services) in all fields of activity, within decision-making processes, and in both local and central public administration-have generated new essential requirements for the workforce, particularly those concerning advanced digital competencies. These are no longer optional; they have become mandatory and refer to advanced skills and abilities in the use of new digital technologies, including awareness of emerging occupational risks, which are continuously analysed by the European Agency for Safety and Health at Work (EU-OSHA). In this context, EU-OSHA monitors and highlights the impact that these developments may have on the nature and organisation of work, as well as the potential risks in the field of occupational health and safety [49][50].

Labour market transformations have now become structural, as they have produced changes in the occupational structure, with a major impact across all sectors of activity, through the emergence of new occupations and/or the modification of tasks associated with existing positions whose requirements have evolved. Thus, through automation, manual and/or repetitive work processes within transformed jobs are partially or fully replaced, while within newly created occupations, new requirements are formulated regarding the competencies and skills needed [51][52].

Goos analyses the impact of technological progress on the labour market through the concrete interaction between workers' competencies and the digital infrastructure in the workplace [53]. Where the workforce lacks adequate qualifications, Goos indicates that direct policy interventions are required in the fields of education and vocational training. In this regard, he highlights the increasing importance attributed at EU level to specialisation in scientific domains (mathematics, computer science, electronics), with the aim of creating a highly skilled labour supply. In the Polish economy, study [29] shows that the new era-defined by technologies based on data flows and their analysis-necessitates the professional training of employees in order to meet the new requirements for knowledge and skills. Thus, digitalisation directly influences not only the labour market, but also the education and

vocational training of both current workers and future job seekers [54][55]. Furthermore, as workers with lower levels of education are exposed to a higher risk of dismissal, it follows that advanced higher education, vocational training, and their continuous improvement constitute significant advantages in securing the future of work and career development [56].

As AI and IoT have become increasingly widespread across all sectors of activity, the importance of specialised competencies in ICT and AI has grown, and, concurrently, the importance of human competencies has increased even further [2]. Traditional occupations, in which manual and/or repetitive work processes can be replaced by AI, are disappearing [57][58][59], while a range of new professions is emerging, requiring new knowledge and skills. These developments generate new challenges in the occupational structure of the labour market, to which both employers and employees must adapt continuously and as rapidly as possible through the acquisition of new competencies. Jobs associated with these new professions generally offer higher-than-average salaries and present significantly faster and more sustained growth prospects than those in other sectors (e.g. specialists in cybersecurity, Big Data, large-scale data administration, designers of complex online platforms, cloud computing, etc.). It is estimated that, in the future, jobs will be digital or will increasingly rely on digital tools, while, at the same time, inequalities in terms of job quality and remuneration will increase [60][61][24]. Author D.H. refers to the rise in wages associated with higher education and the cognitive demands of workers' tasks [62], as well as with the competencies required of them.

In analysing the nature of competencies required by new occupations on the labour market, specialists classify them into technical competencies (hard skills) and non-technical abilities (soft skills), including interpersonal and social skills. Technical knowledge and abilities are acquired through specialised education within higher education institutions, as well as through training and/or professional development programmes, and qualification or requalification schemes [63][64].

As digitalisation intensifies, particularly in the context of the gradual introduction of AI, employers have somewhat reduced the relative importance of specialised ICT competencies, while significantly increasing the importance of human competencies [2]. These mainly refer to empathy, effective communication, teamwork, creativity and inventiveness, accountability, time and project management, conflict management, meeting deadlines, and adaptability to change [65][55][26][20].

Acemoglu and Autor analysed the gender distribution of workers in the ICT sector and observed [26] that women may possess a competitive advantage over men due to empathy and social skills, although they are less oriented towards university studies in Mathematics, Technology, Engineering, and Computer Science. The impact of new technologies is also

felt differently across age groups in the labour market: younger workers, both men and women, tend to adapt relatively easily to changes in technical and social competencies, whereas those aged over 60, particularly without relevant educational backgrounds, face greater difficulties in adapting to the new requirements of the labour market. All these analyses also take into account the higher levels of remuneration associated with new professions [24].

6. Legal and Regulatory Framework Governing Digitalisation and Labour Market Transformation in the European Union

6.1. Introduction to the Legal Dimension of Digital Labour Markets

The transformation of labour markets under the influence of digitalisation, automation, and artificial intelligence is not only an economic and technological process but also a fundamentally legal one. As highlighted in the previous sections, the expansion of ICT, the emergence of new occupations, and the transformation of skills requirements are accompanied by profound regulatory challenges affecting employment relationships, workplace organization, and social protection systems.

Within the European Union, the development of a coherent legal framework addressing these transformations has become a priority, as digitalisation reshapes traditional employment models and introduces new types of work arrangements, including platform work, remote work, hybrid employment, and AI-assisted decision-making processes. These developments raise critical legal questions concerning the classification of workers, protection of fundamental rights, data governance, occupational health and safety, and liability regimes in highly automated environments.

The EU has responded through a multi-layered regulatory approach combining binding legislation, soft law instruments, and strategic programmes such as the Digital Decade Policy Programme 2030 [72][66]. The purpose of this section is to analyse the main legal dimensions associated with the digital transformation of labour markets, in direct connection with the empirical findings previously presented.

6.2. Labour Law Adaptation in the Context of Digitalisation

6.2.1. Transformation of Employment Relationships

Digitalisation has significantly altered the traditional employer–employee relationship, historically based on physical presence, hierarchical supervision, and fixed working hours. The expansion of remote work, digital platforms, and algorithmic management systems has introduced increased flexibility, but also legal uncertainty.

One of the most debated issues concerns the classification of workers in the platform economy. Digital labour platforms frequently classify workers as independent contractors rather than employees, which has major legal consequences regarding:

- social security contributions
- minimum wage protection
- working time regulations
- access to collective bargaining
- protection against dismissal

These developments highlight the need for regulatory intervention at EU level in order to ensure fair working conditions and prevent the erosion of labour rights.

6.2.2. Remote Work and Teleworking Regulation

The expansion of telework has fundamentally transformed work organisation across EU Member States. This phenomenon intensified during the COVID-19 pandemic and continues to shape labour markets.

Telework raises legal concerns related to:

- working time regulation and monitoring
- employer supervision and digital control mechanisms
- occupational health and safety obligations
- cross-border legal jurisdiction issues

In response, regulatory initiatives at both EU and national levels increasingly recognize the right to disconnect, as well as employer obligations to ensure safe working conditions even outside traditional workplaces. These measures are closely linked to broader EU objectives regarding the improvement of working conditions in the digital economy [72].

6.3. Artificial Intelligence Regulation and Its Impact on Employment

The EU Artificial Intelligence Framework

Artificial intelligence has become a central component of digital transformation, with direct implications for labour markets. As previously highlighted in this study, AI influences both job creation and job destruction while reshaping skill requirements [2][4].

The emerging EU regulatory framework adopts a risk-based approach, distinguishing between different categories of AI systems depending on their impact on fundamental rights and social outcomes.

In the context of employment, several AI applications are considered particularly sensitive, including:

- recruitment and selection systems
- performance evaluation tools
- algorithmic management systems
- automated decision-making in HR processes

These applications require enhanced transparency, human oversight, and accountability, in order to prevent discrimination and ensure fairness in employment practices.

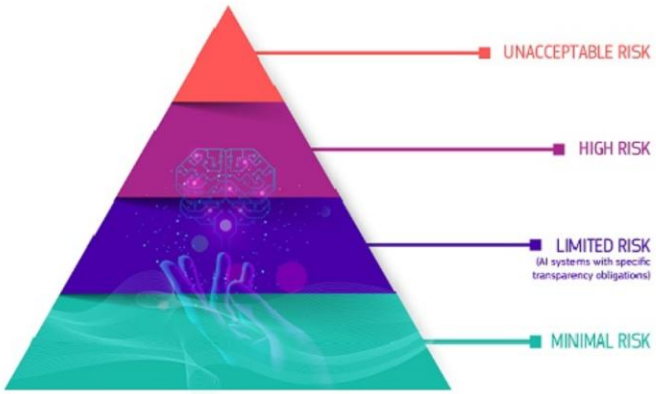

Fig. 7. EU AI regulatory risk pyramid
Source: European Commission – AI regulatory framework, https://digital-strategy.ec.europa.eu/en/policies/regulatory-framework-ai

Algorithmic Management and Worker Protection

The increasing reliance on algorithmic management systems introduces new risks related to:

- opacity of decision-making processes
- potential algorithmic bias
- asymmetry of information between employers and employees
- reduced human control over work allocation

These risks are particularly relevant in highly digitalised economies, where the use of ICT and AI technologies is most advanced [2][66].

In order to mitigate these risks, EU-level policies emphasize:

- transparency of automated decisions
- the right to human intervention
- the prevention of discriminatory outcomes
- the accountability of employers deploying AI systems

6.4. Data Protection and Privacy in the Digital Workplace

GDPR and Employee Data Processing

Digitalisation has led to the extensive processing of employee data, including performance data, communications, and behavioural patterns. As noted in EU-level policy instruments, safeguarding personal data has become a fundamental component of digital transformation [6][66].

The General Data Protection Regulation (GDPR) establishes key principles applicable to the employment context:

- lawfulness, fairness, and transparency
- purpose limitation
- data minimisation

- accuracy and storage limitation
- accountability

Employees benefit from rights such as access to their data and protection against fully automated decisions, which are essential in a digital labour market environment.

Fig. 8. Key GDPR principles applicable to employee data
Source: https://trainingcred.com/blog/employee-data-and-gdpr-compliance-ensuring-privacy-in-the-workplace

Workplace Monitoring and Surveillance

The use of digital monitoring tools-such as tracking software, productivity analytics, and biometric systems-has increased significantly.

However, EU legal frameworks require that such practices:

- respect proportionality and necessity
- serve legitimate business purposes
- ensure transparency towards employees
- preserve human dignity and privacy

These requirements reflect the broader EU commitment to balancing technological innovation with fundamental rights protection [49][50].

6.5. Occupational Health and Safety in Digital Work Environments

Digitalisation introduces new occupational risks that extend beyond traditional workplace hazards.

Psychosocial Risks

As highlighted by EU-OSHA, digitalisation contributes to:

- increased work intensity
- constant connectivity
- blurred boundaries between work and personal life
- higher risks of stress and burnout

These psychosocial risks are increasingly recognized as part of occupational health frameworks [49][50].

Ergonomic and Physical Risks

Remote work environments may lack proper ergonomic conditions, leading to:

- musculoskeletal disorders
- visual fatigue
- long-term health issues

Employers remain legally responsible for ensuring safe working conditions regardless of work location.

AI and Safety-Critical Systems

In sectors involving AI-assisted decision-making (e.g., transport, healthcare), safety requirements include:

- system certification and testing
- human oversight mechanisms
- clearly defined liability structures

These requirements reflect the integration of technological and legal standards in digitalised economies.

6.6. Skills, Education, and Legal Policy Frameworks

6.6.1. Lifelong Learning and Legal Policy

The transformation of labour markets requires continuous adaptation of workforce skills. EU initiatives emphasize lifelong learning as a legal and policy priority, supporting:

- reskilling and upskilling programmes
- access to digital education
- alignment of education systems with labour market needs [73][66]

These measures directly address the structural changes highlighted in previous sections.

6.6.2. Recognition and Standardisation of Digital Competencies

The need for harmonised skill frameworks has led to the development of European-level competency standards.

Feature	Traditional Employment	Digital Employment
Workplace	Physical	Remote / hybrid
Supervision	Direct (human)	Algorithmic / digital
Contracts	Standard labour contracts	Platform/flexible
Skills	Stable	Continuously evolving

Protection	Strong (standard)	Often fragmented

Table 2. Comparison between traditional and digital employment models
Source: authors research

These frameworks contribute to labour mobility and ensure consistency in competency recognition across EU Member States [69].

6.7. Social Protection and Inequality in the Digital Economy

Digitalisation may exacerbate inequalities if legal protections are not adapted.

Social Security and Non-Standard Employment

Non-traditional forms of employment may lack adequate social protection. EU-level policies aim to address:

- gaps in social security coverage
- portability of benefits
- inclusion of platform workers

Gender and Age Inequalities

As indicated in previous sections, digitalisation affects demographic groups differently [74]. Legal and policy frameworks seek to:

- reduce gender gaps in ICT employment
- support older workers' adaptation
- promote inclusive labour markets

Regardless of the demographic groups, the following skills are the most desired and relevant for the near future:

Fig. 9. Future skills demand
Source: World Economic Forum, https://www.weforum.org/stories/2023/05/growth-summit-2023-youth-work-skills/

6.8. Liability and Responsibility in Automated Systems

The increasing use of AI raises complex issues of legal responsibility.
Key challenges include:

- attribution of responsibility for AI decisions
- determination of liability in case of system failure
- evidentiary difficulties in automated environments

EU initiatives aim to clarify these issues through updated regulatory frameworks and liability rules, ensuring trust in digital technologies.

6.9. Synthesis: Legal Implications of Digital Labour Market Transformation

The transformation of labour markets under digitalisation is closely linked to the evolution of legal frameworks in the European Union.
The analysis highlights that:

- labour law is adapting to new forms of work
- AI regulation is central to employment governance
- data protection has become a core labour right
- occupational safety must address digital risks
- education policies are legally embedded in labour strategies
- social protection systems must evolve to prevent inequality

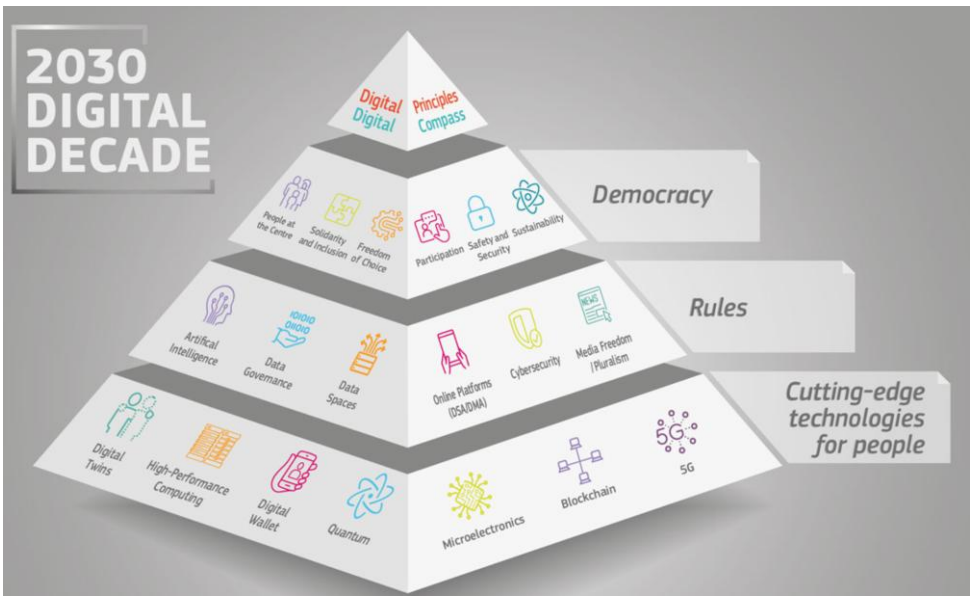

Fig. 10. EU Digital Decade targets (2030)
Source: https://www.seam.earth/sustainable-news/europes-digital-decade/

These legal developments provide the institutional foundation necessary to support the structural transformations of labour markets identified in the empirical analysis of this study.

7. Discussion

At present, an increasing number of employees are experiencing the disappearance of certain automated jobs, alongside changes in the requirements for digital knowledge and communication skills associated with their positions. At the same time, employers face vacant positions that require digital competencies, for which suitably qualified individuals-either with higher education in the relevant fields or capable of being trained through additional programmes-should be available.

Although approximately 55.6% of Europeans possess at least a basic level of digital skills [66], there remains a limited number of ICT specialists with advanced competencies, alongside a significant gender gap. This situation hampers progress in key ICT sectors, such as the storage, analysis, and protection of large volumes of data, robotisation, the expansion of IoT, cybersecurity, and artificial intelligence.

To support workers in the digital sector, as well as those applying for such positions, a number of specialists and researchers, together with educational and vocational training institutions, have identified, synthesised, and published these new competencies and skills, which are increasingly in demand on the labour market.

Bernard Marr argues that, at present, in-depth technical knowledge is less important for workers than understanding the impact that advanced ICT technologies will have on work in the future, and that most of the required skills will be non-technical, related to human states and/or activities that machines cannot perform [67]. However, many of these skills are not taught or developed within traditional educational systems, which are primarily focused on training specialists in the field.

The UK Government's Department for Education has developed a guide aimed at explaining and exemplifying these fundamental digital competencies required in a continuously evolving labour market [68], as well as additional skills such as communication, information management, problem-solving using online services, awareness of data visibility in online environments, and the risks to data protection and confidentiality. As ICT evolves more rapidly and advances towards artificial intelligence, both specialised technological competencies and workers' personal skills become increasingly important.

In this context, it is necessary to establish a unified definition at EU level of ICT occupations and professional profiles, as well as the specific and personal competencies required of workers. Study [69] analyses three existing reference frameworks for defining similar competencies within the EU: *the e-Competence Framework e-CF (EN 16234-1:2016), ESCO (European Skills, Competences and Occupations classification)*, and the *European ICT Body of Knowledge* - and highlights the need to create a unified standard that integrates all these competencies, skills, knowledge, and qualifications. This framework, referred to as e-Skills Match, could ensure the use of a common language for a consistent understanding of the specific requirements of different ICT roles across EU countries, facilitate the mobility of professionals within the EU, and support the alignment of education with the specific demands of work in terms of the new competencies and skills required [70].

Technological development, automation, and the digitalisation of all economic, social, and cultural domains, together with investments in innovation and research and development across EU countries, will lead to the disappearance of certain occupations and a large number of jobs, while also generating new challenges and opportunities in an ever-changing labour market. These developments will give rise to the jobs of the future, most of which will be digital in nature or will rely heavily on digital tools.

For workers with a low level of education, the risk of job loss is significantly higher than for those with higher levels of education, which necessitates the acquisition and development of new competencies demanded by the labour market through continuous education, higher education, or vocational training. In order to ensure the continuous and up-to-date qualification of the workforce, a system of lifelong learning is required, in which ICT educational programmes are designed with a modular, flexible structure that can be easily adapted to the acquisition of new competencies required by the labour market [71].

8. Conclusions

The evolution of occupations will undoubtedly entail the adoption of measures, policies, and regulations within EU countries aimed at coordinating and stimulating the adaptation of workers, the unemployed, and the working-age population to the new technical and non-technical competency requirements demanded by the labour market.

Accordingly, the European Parliament, the European Commission, and the EU Member States have established and are cooperating in the implementation of a set of policies necessary to achieve the EU's digital objectives by 2030 [72][9]. There are new ICT domains in which hundreds of thousands of jobs remain vacant and are difficult to fill on the labour market, requiring specialists in areas such as cybersecurity, data analysis, machine learning and artificial intelligence, Big Data, business intelligence analysis, software and applications development, data analytics, as well as engineering in green energy and electric vehicles [18][65][73].

Consequently, the education system in EU countries must become more flexible and adapt to the new requirements of the labour market, in order to provide-alongside the specialised knowledge necessary for automation and digitalisation-the non-technical competencies and skills required by emerging professions.

All these developments will contribute to reducing the adjustment period of the labour market to the new context of technological and ICT-driven development, thereby supporting the transition towards balancing labour supply and demand.

Researchers have also examined the relationship between the growth of competencies and wage increases in new occupations requiring higher levels of education, vocational training, or qualifications. Furthermore, they have found that new labour market positions are increasingly attracting young and working-age women into employment across various highly automated and digitalised sectors [74].

All these aspects demonstrate that the labour market, in its continuous transformation, has profound implications not only for employment and unemployment, economic growth, and specialisation in ICT-related fields, but also for population well-being, the promotion of gender equality in the labour market, and the reduction of gender disparities.

The conclusions of this analysis may assist policymakers in EU countries in shaping policies aimed at stimulation, adaptation, and increased flexibility in higher education and vocational training systems, as well as in investment in research and development and occupational health and safety activities. This implies that the analysis should be continued in order to identify and measure the factors contributing to the growth of digitalisation, the transformation of specialised higher education, the sectors driving economic and ICT development, and labour market behaviour with regard to reducing gender disparities.

Abbreviations

AI = Artificial Intelligence
IoT = Internet of Things
EU-OSHA = European Agency for Safety and Health
ILO = International Labour Organization
WEF = World Economic Forum

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