

Forecasting of the Employment Rate in the EU ICT Field

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Abstract

The ingrained tendency to implement information and communication technologies (ICT) in EU enterprises over the last decade has caused dramatic changes in the labor market. Since the demand for ICT personnel is growing, there is still a need to create a comprehensive strategy to effectively manage ICT specialists when restructuring enterprises. The aim of the research is to identify transferring processes between low- and high-skilled ICT personnel and predict the employment rate in the ICT field until 2025. A Markov chain was used as the method of analysis. Using statistical data about the employment rate of ICT personnel by education attainment level, we have built a Markov chain model that describes the processes of ICT personnel with different levels of education. Data from 2005 to 2019 was used to build forecasting because of the absence of the latest information. We demonstrate that with the help of digitalization, the employment rate of ICT staff in 2025 will increase by 64% compared to 2018. The research verifies that ICT personnel will be in great demand until 2023 and, importantly, low- and middle-skilled personnel will be in demand, as well as high-skilled personnel. The employment rate in the ICT field will be at its highest level in 2022 as the favorable economic conditions for ICT



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adoption will help it. The growing demand for low- and medium-skilled ICT staff are met both by staff relocation processes and by the increasing digitalization of business units and public sector institutions. The added value of the analysis is the prediction that the largest growth in ICT personnel employment will occur by 2023, but employment growth will slow down after that. The main obstacle to employment growth through digitalization is the global economic crisis because of different reasons.

Keywords: ICT adoption, digitalization, employment management, labor demand, Markov chain

JEL: J23, F17, F66, O32, O52

Introduction

The increasing trend of e-commerce and the implementation of information and communication technologies (ICT) systems led to significant changes in the labor market. The most visible effect can be seen in the employment rates of personnel who differ by education attainment level. Widely available self-study resources and the high pace of digitalization forced employees to transfer between qualification levels. All middle and low-skilled ICT personnel can be promoted to the high-skilled group. However, according to statistical data, the demand for high-skilled personnel is not big as for middle- and low-skilled personnel.

Given the current scientific debate on the nature of the impact of digitization on the labor market, research-based Markov chain modeling was conducted. The purpose of this article is to verify the transferring processes between ICT employees with different educational attainment levels. The most recent statistics (2005–2019) were used for the analysis to build forecasting. The scientific novelty of this research is the comprehensive analysis of the transition of ICT personnel with different educational attainment levels using Markov chain modeling. The results of the study can be used to build integrated strategies to engage staff with different qualifications in the technological restructuring of EU enterprises.

Literature review

The intensive development of e-business and e-commerce, and the increasing tendency to implement ICT motivate researchers to analyze the impact of digitalization factors on the employment rate of the population by qualification level. For our research, we reviewed relevant scientific papers that described the economic effect of implementing ICT and e-commerce on the labor market using econometric and data science methods. There is no doubt that there is a significant positive correlation between worldwide ICT adoption and economic growth (Amiri, Dodson, and Woodside 2015; Jorgenson and Vu

2016; Latif et al. 2017), but structural changes in labor demand should be prevented by an effective employment strategy.

Herman (2020) showed changes that personnel faced due to digitalization. It was reported that 21% of personnel in the EU have had their working tasks changed, and 39% needed to learn how to work with new technologies. The same results were obtained by Goaid and Sassi (2019) using data science. They showed that from a long-time perspective, ICT adoption caused global structural unemployment in developing and developed countries.

Falk and Biagi (2016) gave a detailed analysis of the impact of ICT on the highly skilled labor employment rate in seven European countries. They identified the significant impact of ERP and e-commerce on the employment rate of highly qualified staff using a panel-based model. They claimed that with a 10% increase in European enterprises that use ERP systems, the share of highly qualified labor employment increases by 0.4%. Thus, between 2001 and 2010, the proportion of highly qualified staff employed in seven European countries increased by 30%, demonstrating the positive effect of e-commerce and ICT on the employment rate of highly skilled staff. Similarly, Peters et al. (2017) showed the positive impact of ICT implementation on the employment rate in high-tech industries.

Balsmeier and Woerter (2019) focused on the impact of ICT and e-commerce on job creation. They examined in detail the tendency to eliminate low-tech jobs when implementing innovative solutions in 28 European countries. Their research was based on an econometric model of the impact of investments when implementing e-commerce systems and the digitization of workflows on the employment rate of staff with different levels of qualification. The econometric model based on panel data included parameters such as investments in digital technology, e-commerce and R&D, employment rates of high-, middle- and low-skilled staff, and the implementation of high-tech solutions in enterprises. They statistically confirmed that investing in e-commerce positively correlates with the employment rate of highly skilled workers and negatively correlates with the employment rate of low-skilled workers. Thus, e-commerce, as a whole, has a net positive impact on employment.

Pantea, Sabadash, and Biagi (2017) also confirmed that the implementation of ICT in European enterprises has no negative impact on employment. The results of their study are significant and reliable for seven European countries. It is important to analyze ICT effects at the country level, as well as at the sectoral level. Abramova and Grishchenko (2020) demonstrated that when adopting ICT, labor productivity rose, but there is a possibility of industrial unemployment due to unsustainable processes in some sectors.

The empirical study by Dachs et al. (2016) described the effect of “cannibalization” when, in the context of the innovative development of European enterprises, the growth

of highly skilled labor is accompanied by a proportional decline in low-skilled personnel employment. They argued for the net positive effect of enterprise innovation on employment growth in most industries. A similar result was presented by Arenas Díaz, Barge-Gil, and Heijs (2020), who investigated the impact of developing innovative enterprises on the change in the employment of high- and low-skilled personnel in Spain. They confirmed that about 13.3% of the gap in employment rate between the two different groups of personnel can be explained by the effect of implementing innovations. They confirmed the net positive effect of e-commerce on the employment rate.

Similar results were obtained by researchers studying the impact of e-commerce and ICT in selected countries. An econometric study by Bockerman, Laaksonen, and Vainiomaki (2016) demonstrated the emergence of the polarization of labor demand in Finland due to the rapid pace of innovation in enterprises. Fukao et al. (2020) provided quantitative arguments for the positive link between investment in ICT, the employment rate, and wages of highly qualified personnel in Japan and Korea. The risks of the negative impact of ICT on the employment of low- and medium-skilled personnel have also been investigated (e.g., Arntz, Gregory, and Zierahn 2016; Frey and Osborn 2017). Using modeling of the computerization development of business, the demand for the workforce of different skill levels in the near future was analyzed (Falk and Hagsten 2018).

In contrast to previous research, Spiezia, Polder, and Presidente (2016) identified the neutral impact of information and communication technology implementation on labor demand using regression models based on annual data of OECD countries. He argued that the rapid development of ICT eliminates jobs in proportion to the creation of new jobs. Thus, there is a shift in the workforce, from a highly-skilled group of staff, who have insufficient potential to perform new tasks in the innovation field to a group of low-skilled personnel, and vice versa – the transfer from low-skilled workers, who quickly adapt to new challenges, to high-quality staff.

A series of studies indicate the high negative correlation between ICT implementation and routine jobs and prove the trend towards the popularization of outsourcing. In their study on 28 OECD countries, Marcolin, Miroudot, and Squicciarini (2016) confirmed that ICT has a positive impact on the employment rate in innovative job places as well as in routine jobs. Importantly, high-routine jobs are displaced by digitalization. Corresponding results were obtained by Brambilla and Tortarolo (2018) on data from an Argentinian manufacturing company. The main aim of their study was to indicate whether ICT adoption displaces low-skilled labor or not. The results show that the employment rate of personnel with all skill levels increased, but there was a substitution of unskilled workers by personnel with higher education attainment levels. So, there is a high correlation between tasks routines, ICT adoption, and employment rate (Cirillo et al. 2020). Additionally, Falk and Biagi (2015) demonstrated a trend for increased high-skilled ICT

workers due to digitalization in Europe, although modern technologies did not displace low-skilled workers.

Dosi and Mohnen (2019) wrote about the polarization of jobs as a result of digitalization. Their study excluded a possible negative correlation between ICT and employment rates as due to technological restructuring, personnel acquires new skills. Furthermore, digitalization leads to globalization as the main source of knowledge for labor.

Unique research was conducted by Flynn, Dance, and Schaefer (2017), who studied the readiness of EU countries in the manufacturing sector to adopt ICT. The UK was found to be most prepared for ICT implementation as digital penetration in government, business, and education sectors was at the highest level (before Brexit). The UK, although no longer part of the EU, is second to Germany in the number of ICT specialists. Studies have demonstrated that it is vital to support ICT adoption by investments in the R&D and education sectors. The importance of ICT education for the Nigerian agricultural sector and economic growth was explained by Agwu (2015), while Anicic, Divjak, and Arbanas (2017) explained the problem of ICT education. Studies also provide cluster analysis and confirm the need to improve education programs for future ICT workers worldwide as it does not suit real-world issues.

Thus, given that the vast majority of studies prove the positive or neutral impact of ICT and e-commerce on the employment rate in different countries, there is a need for a detailed analysis of the probabilities of staff leakage, which is directly dependent on the nature of the development of ICT in European Union (EU) enterprises (Dluhopolskyi et al. 2019; Koziuk et al. 2020; Dluhopolskyi et al. 2021; Oleksiv et al. 2021; Panchenko et al. 2021). The main aim of the study is to identify the nature of the flow of ICT employees between high and low education attainment level groups and also to forecast employment rates in the ICT field for future periods. The object of the study is the employment rate in the ICT field in EU countries. Statistical data, unified standards, and European directives allowed us to combine the national ICT markets in EU countries, as it is a single European digital space.

Methodological approach

To quantitatively analyze the dynamics of ICT personnel employment rate by education attainment level, a Markov chain model was chosen (Tolver 2016). The Markov process is a “stochastic model describing a sequence of possible events in which the probability of each event depends only on the state attained in the previous event” (Gagniuc 2017, p. 62). Using this methodology makes it possible to analyze the flow of staff between

two groups of ICT skills, as well as predict the dynamics of the employment rate of ICT personnel by education attainment level.

In general, using Markov chain methodology can create a model that will help generate transferring processes between different groups of labor divided by education attainment level.

The Markov chain is a stochastic model that explains the sequence of possible events, and the probability of the occurrence of each subsequent event depends only on the previous event. In general, the Markov chain model looks as follows:

$$p_{ij} = P\{x_t = j | x_{t-1} = i\}, \quad (1)$$

where $i, j = \overline{1, 2}$.

The transition probability matrix will then look like this:

$$p_{ij} = \begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix} \quad (2)$$

Each row of matrix (2) is a probability distribution, i.e., the coefficients of each line are equal to one:

$$\begin{cases} p_{ij} \geq 0 \\ \sum_{i \in \mathbb{E}} p_{t-1, t}^{ij} = 1, \end{cases} \quad (3)$$

where $i, j = \overline{1, 2}$ i $t = \overline{1, 14}$.

It is necessary to verify the stationarity of the simulated process. The process is stationary if $p_{ij}(t)$ is not time-dependent. The stationary testing hypotheses look as follows:

$$\begin{cases} H_0 : p_{ij}(t) = p_{ij}, t = \overline{1, 14} \\ H_0 : p_{ij}(t) = p_{ij}, t = \overline{1, 14} \end{cases} \quad (4)$$

In this case, the homogeneity test χ^2 can be used to test the above hypotheses:

$$\chi_i^2 = \sum_{ij} \frac{n_i(t-1) \left(\widehat{p_{ij}(t)} - \widehat{p_{ij}} \right)^2}{\widehat{p_{ij}}}, \quad (5)$$

where n – number of possible conversions, $i, j = \overline{1, 2}$ i $t = \overline{1, 14}$.

For the Markov chain modeling, a software environment R was used with the Markov-chain function package required for modeling Markov processes (Spedicato 2020). Based on the estimated transition probabilities matrices, it will be possible to create forecasts of the transfer probabilities of personnel by education attainment level in the future and estimate each qualification group's employment rate.

The methodology of the study consisted of three main parts:

1. Data verification.
2. Modeling the transition graph.
3. Model verification.

With the help of the first part, it can be decided whether our data is appropriate for Markov chain modeling. To verify the data, the Markov property function from the Markov-chain function package should be used. If the p-value of the verification output is bigger than 0.05, the data row satisfies all necessary conditions for Markov chain modeling.

A transition graph can be created by using the same package in R. Using a general equation, this function automatically generates a graph based on previous data tendencies. The results of the modeling should be verified using qualitative and quantitative methods. Firstly, the χ^2 homogeneity test should be used and the next step is a logical discussion of modeling results. In general, the model should be statically verified based on previous data. The logical test can be provided on prediction results and historical databases.

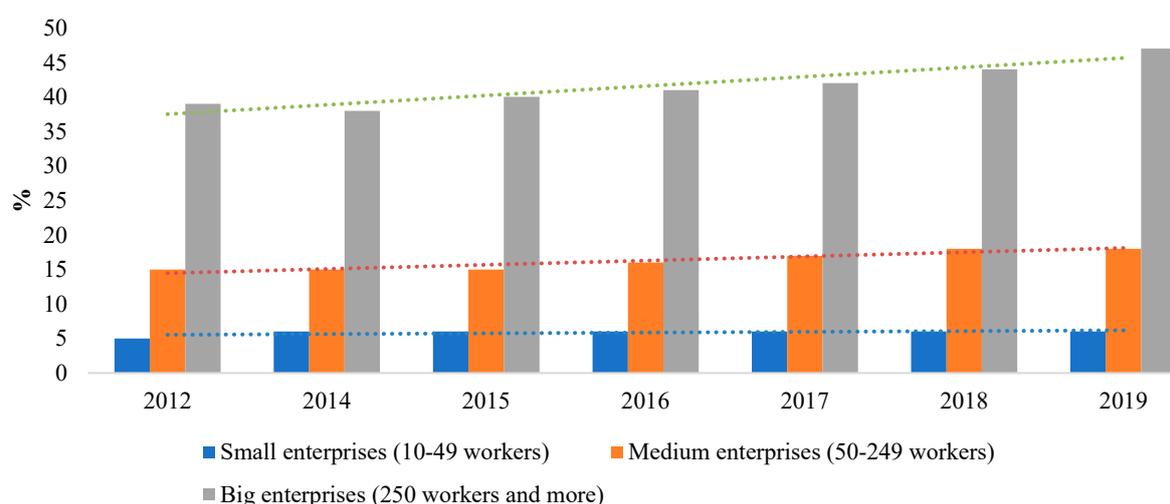
Thus, to conduct the research, annual data during the period 2005–2018 on the employment of high- and low-skilled workforce in ICT will be used, and the possibilities of transferring between the two groups of personnel qualifications will be evaluated.

The relationship between the rapid development of ICT and e-commerce and the employment rate is a widely debated theme within the EU and globally. Studies vary in their results. Some argue the net positive effect of investment in innovation on the employment rate, while others highlight the significant negative effect, which means that innovations increasingly destroy jobs.

Our previous works (Zatonatska and Dluhopolskyi 2019; Zatonatska et al. 2019; 2021; Zatonatska and Fedirko 2019) demonstrated the positive e-commerce effect on the employment rate of the EU population using regression modeling. Specifically, the aim was to verify the existence of transferring processes between different groups of employees by education attainment level who are causally related to ICT. It is assumed that due to digitization and widely available self-study resources, there was a tendency to gradually transfer ICT employees from medium and low-skilled technical staff

into the category of highly skilled labor from 2005 to 2019. There is also a hypothesis that over the next five years, the rate of transfer will increase, and the probability of becoming high-tech staff will gradually increase.

Given that the implementation of innovative solutions in e-commerce and ICT is rapidly expanding, it is advisable to assume a growing trend of demand for qualified technical staff. Graph 1 shows the dynamics of the proportion of EU enterprises by size employing or seeking to hire workers with ICT knowledge. It shows a clear upward trend in the share of large and medium-sized enterprises employing ICT staff. Between 2012 and 2019, the share of large enterprises employing ICT staff increased by 8%, and the share of medium-sized enterprises increased by 3%. Therefore, considering the above-average wage levels of workers with e-commerce and ICT qualifications and the cost of innovations required, the tendency to increase the proportion of small businesses employing ICT staff is not evident. So, the demand for skilled ICT personnel is generated by large and medium-sized enterprises to a greater extent.



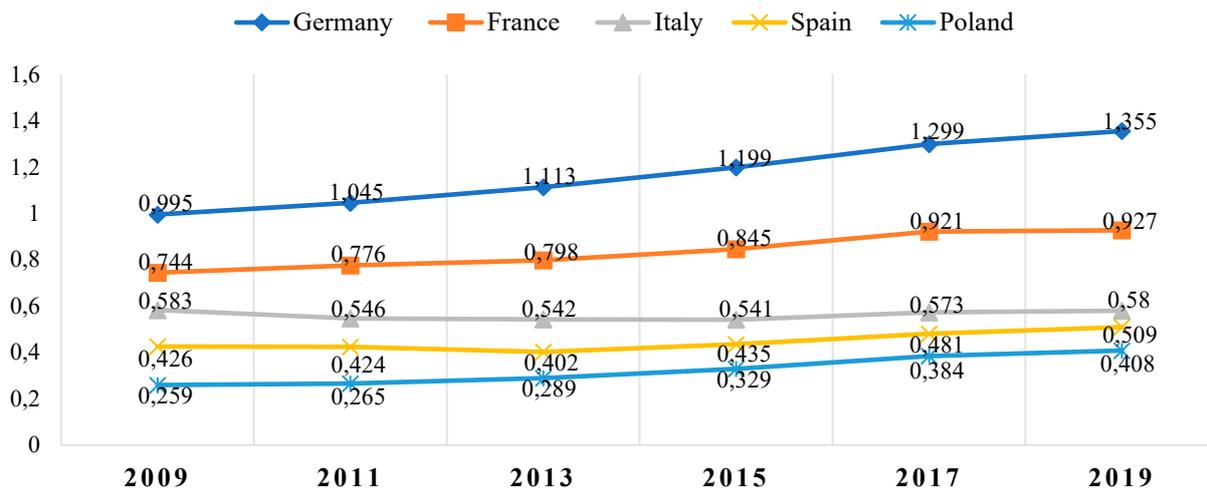
Graph 1. Share of EU enterprises that hire ICT specialists

Source: compiled by authors based on Eurostat (n.d.).

Among the new EU Member States, the largest number of people employed in ICT was recorded in 2019 in Poland (more than 408,000, of whom 3/4 are employed in the services sector). According to this indicator, Poland is among the Top 5 countries with the largest number of ICT specialists (Graph 2). Other new EU members with a high number of ICT employed include Romania (more than 203,000), the Czech Republic (more than 147,000), and Hungary (more than 138,000).

The ICT industry now constitutes about 8% of Polish GDP, and the number of employees increases by 5–6% annually. The revenues of the Polish IT sector in 2018 amounted to EUR 16 billion. The structure of the IT market in Poland: 55% – IT equipment sales, 16% – software, 29% – services (Rutkowski 2019). The top five recipients of Polish IT/

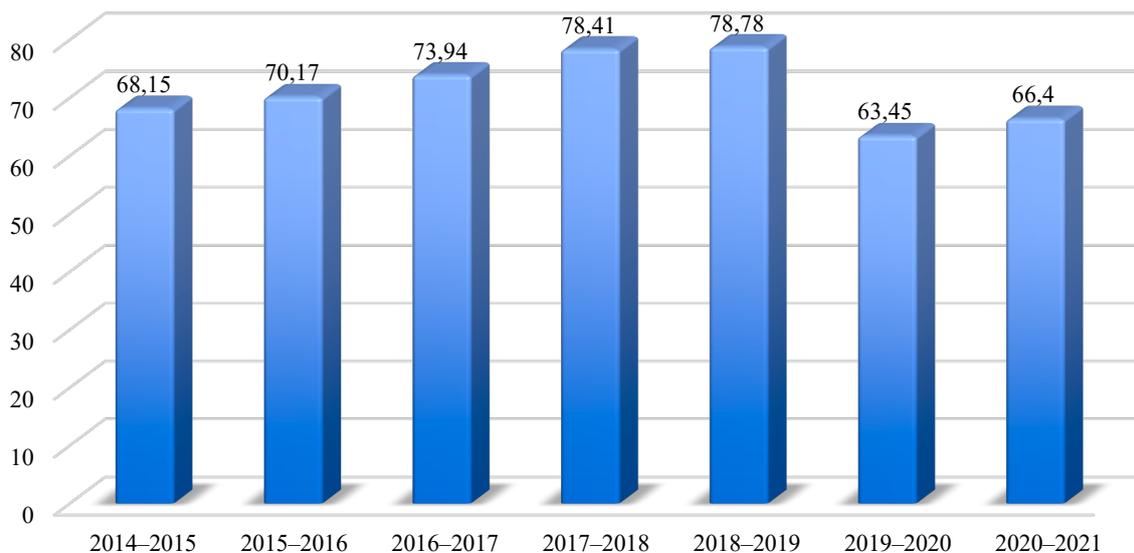
ICT services are the UK (€967 million), the USA (€889 million), Switzerland (€732 million), Germany (€715 million), and Sweden (€321 million). The two main business models of IT companies operating on the Polish market are sales of infrastructure under public contracts and the production of custom software together with staff outsourcing. In 2017, expenditures on cloud technologies in Poland amounted to nearly €200 million, and the International Data Corporation (IDC) forecasts that by the end of 2022, the cloud technology market will reach €450 million (Rutkowski 2019).



Graph 2. Top 5 EU countries by number of people employed in ICT, millions

Source: compiled by authors based on Nation Master (2022).

Given the number of ICT students in Poland (Graph 3), the country is well prepared for the growth of the share of this sector in the country’s GDP in the future.

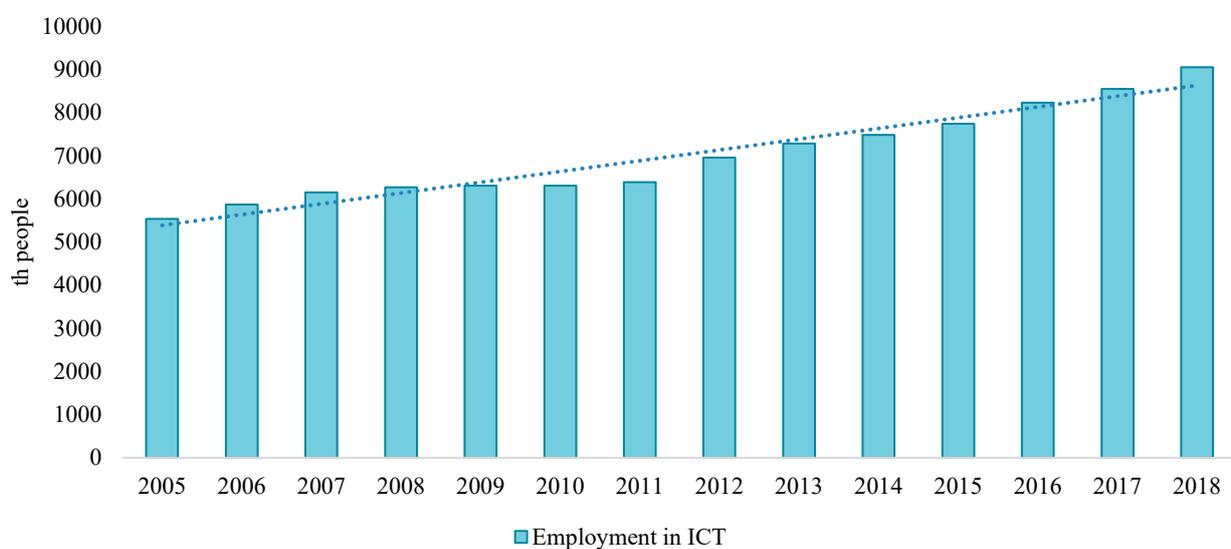


Graph 3. Number of students who studied ICT in Poland, in thousands

Source: compiled by authors based on Statista (2022).

Let us also consider the dynamics of the ICT staff employment rate in the EU countries (Graph 4). Graph 4 shows an upward trend in the level of employment of ICT specialists. Thus, between 2005 and 2018, the employment rate of staff with ICT education increased by 64%. Moreover, the rapid increase in employment and the demand for ICT staff started precisely in 2012, which is due to the increasing tendency to implement innovative solutions. Therefore, in 2012, the employment of ICT staff in European countries increased by 30%.

Given that the main purpose of our study is to analyze and forecast the employment of highly educated staff in ICT, it is necessary to investigate the employment rate of ICT staff by educational attainment level (Graph 5).



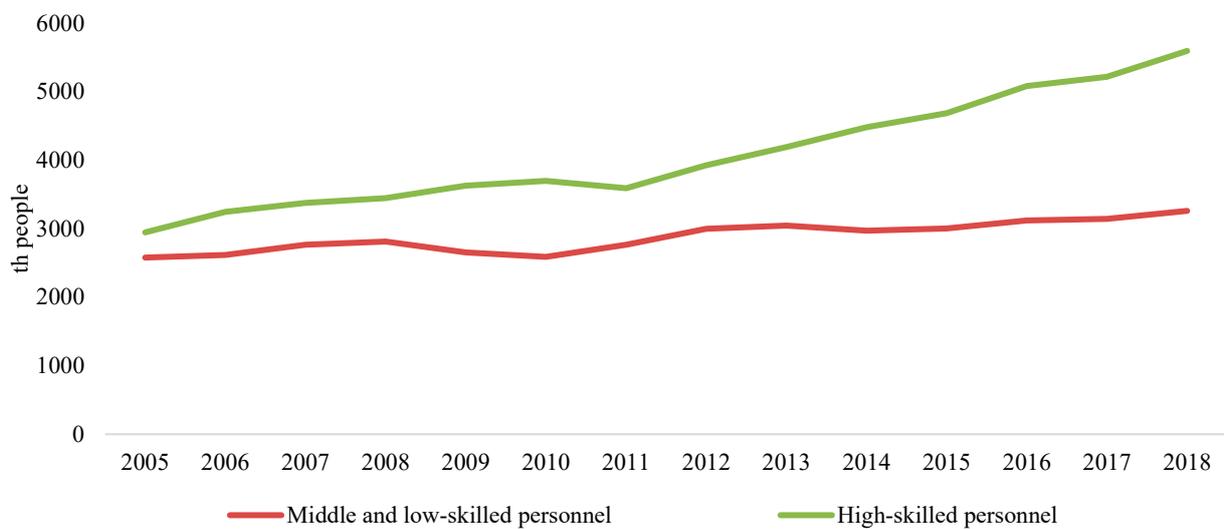
Graph 4. Employment of ICT personnel in the EU

Source: compiled by authors based on Eurostat (n.d.).

For our research, two groups of ICT staff were chosen by educational level – highly educated (workers with higher education in the relevant field, certified staff) and low educated (category of workers with lower or secondary education attainment level). There was a tendency to increase the employment rate of highly qualified personnel from 2005 to 2018. Moreover, the growth rate of highly qualified personnel employment exceeded the growth rate of low-skilled ICT personnel employment by 50%. So, it is assumed that in the future, there will be a demand for ICT specialists at the expense of a highly educated workforce. Thus, there will be an increasing tendency to promote higher education in this area, specialized courses, and as a result, transferring between lower and higher educated groups of employees.

All in all, given the analyzed statistical data on the employment rate of ICT personnel by educational attainment level, it is imperative to verify the hypothesis of the ex-

isting transfer of ICT staff with different educational attainment levels and to predict the future dynamics of the employment of high- and low-skilled personnel in ICT.



Graph 5. ICT personnel employment rate in the EU by education attainment level

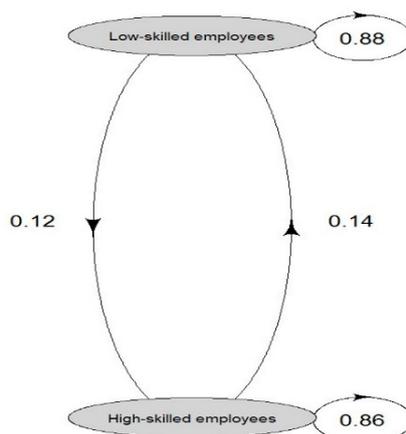
Source: compiled by authors based on Eurostat (n.d.).

Conducting research and results

First, the selected data series should be checked for Markov chain applicability. Using the verify Markov Property function, it can be verified that the selected sequences of values (employment of high-skilled/middle- and low-skilled ICT staff) match the Markov chains requirements. Since the p-value is more than 0.05 in this case, the null hypothesis is accepted, which means that the data series satisfy the necessary conditions for modeling using Markov chains.

To estimate the trend of ICT personnel overflow during the period 2005–2018, a transition graph was constructed. The transition graph for the flow of ICT staff between two qualification groups during the period is presented in Graph 6. There is a significant probability of remaining in the previous qualification group during the period. Thus, for high-skilled technical staff, the probability of staying at the previous qualification level is 86%, and there is a 14% probability of transitioning to the low-skilled group due to the lack of ICT qualification.

The results of the assessment above are fully in line with the previous studies that verified the ingrained tendency to transition between qualification groups of ICT specialists. Moreover, the probabilities determine the upward trend in the employment rate of highly qualified personnel, which is proof of the hypothesis that the demand for highly qualified personnel is growing.



Graph 6. The transition graph of ICT employment by education attainment level

Source: compiled by authors based on model results.

The comparison of transition probability matrices that are relevant for 2010 and 2019 are shown in Table 1. Until 2019, tendencies to transfer between qualification groups changed.

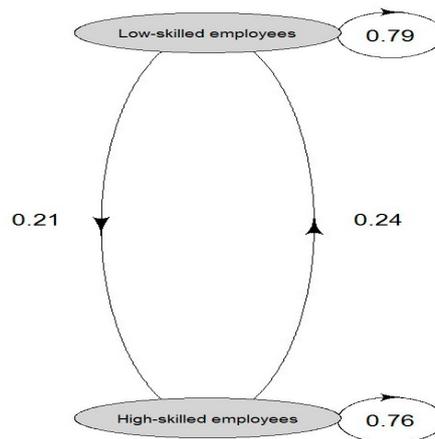
Table 1. Transition matrices for the two qualification groups of ICT employees, 2010–2019

2010			2019		
	High-skilled employees	Low-skilled employees		High-skilled employees	Low-skilled employees
High-skilled employees	0.88	0.12	High-skilled employees	0.84	0.16
Low-skilled employees	0.08	0.92	Low-skilled employees	0.13	0.87

Source: compiled by authors based on model results.

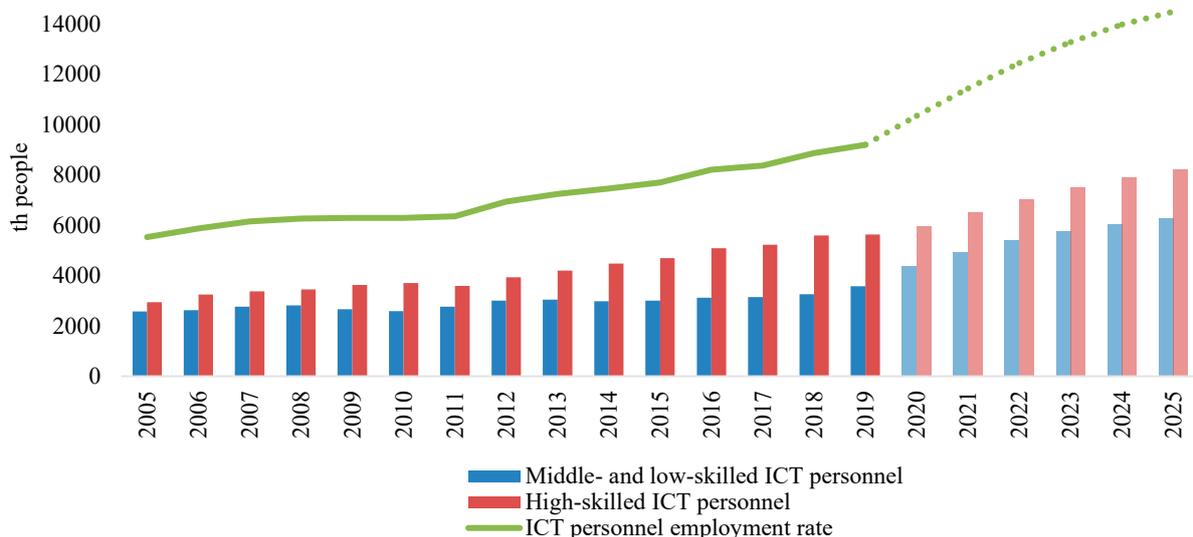
Graph 7 presents the transition probability that is relevant for 2020. It is important to note that 2018 is the starting point for the construction of this graph. The forecast of employment of high- and low-skilled personnel in ICT was calculated based on the probabilities of transitions between states. Thus, in 2020, the employment rate of high-skilled ICT personnel in EU countries was 5.97 million people, which is 7% higher than in 2018, and employment of low-skilled personnel was 4.37 million people (+34% to 2018). This tendency can be explained by the popularization of the direction and, consequently, the increasing level of self-study opportunities in this field. The overall employment rate will increase by 17% compared to 2018.

By modeling the transition probabilities of ICT staff step by step, we obtained a forecast of ICT staff employment by 2025. The simulation results are shown in Graph 8.



Graph 7. The transition graph of ICT employment by education attainment level

Source: compiled by authors based on model results.



Graph 8. Prediction of ICT personnel employment in the EU for 2020–2025

Source: compiled by authors based on model results.

According to the Markov-based modeling, the employment of ICT staff will increase by 64% by 2025 compared to 2018. It is also important to note that the employment of medium- and low-skilled staff will grow faster than the employment of high-skilled ICT professionals, to a greater extent provided by the transfer of staff from lower qualifications. Moreover, employment growth will be at its highest rate in 2022 due to favorable economic conditions in Europe for innovation implementation and the urgent need for economic growth.

With the help of Markov chain modeling, the presence of transitioning between qualification groups and the prediction for ICT employment rate in EU countries were confirmed.

Discussion

Digitalization can create job opportunities as well as destroy them. In this research, the positive correlation between ICT implementation and the labor market was statistically proven. It is important to note that ICT and e-commerce popularization destroys dozens of labor opportunities, but the key fact is that it creates more than destroys.

It is discussed worldwide that due to global digitalization, low-skilled staff has become useless in developed enterprises as high-skilled labor displaced them. Using an econometric model, our study confirmed that the employment of low-skilled staff is going to grow as ICT and e-commerce implementation facilitates it. Specifically, ICT implementation helps reduce labor demand. However, staff who develop new technologies (high-skilled staff) and those that serve existing technologies and processes (middle- and low-skilled staff) will also be in high demand.

Enterprises can optimize labor demand by giving them the type of work that suits them. Our research refers to the fact that digitalization destroys those types of workplaces that are old and unproductive and creates new ones that are progressive. By progressive job opportunities, we mean workplaces that hire all types of staff, high- and low-skilled, but require a new vision and the ability to adapt to modern processes.

The main obstacle for the employment rate growth through digitalization is global economic crises. In the case of economic crises, enterprises will face new challenges that require technological restructuring. However, the consequences cannot be predicted using data science methods. Qualitative analysis may lead to the conclusion that low-skilled staff may be replaced by higher-educated labor. However, it is undeniable that until the start of a global economic crisis, low-skilled personnel will be transformed into medium-skilled staff, and digitalization will neither create nor destroy workplaces.

According to statistical data on European enterprises that try to hire ICT specialists (Graphs 1–3) and the ingrained growing trend of employment rates of ICT staff, the demand for ICT specialists will be met by 2025. Additionally, widely available studying resources will contribute to the supply of qualified ICT staff. So, up to 2023, the pace of employing ICT personnel will rapidly rise due to the enabling conditions (available education and demand for ICT staff). However, from 2025, ICT employment will be stable.

Conclusion

To study the impact of e-commerce and ICT on the employment of highly qualified and low-skilled personnel, the EU ICT employment market was taken, which operates based on unified standards, uniform norms, and rules, and has an appropriate statistical

base. The results of the study can be used to build a comprehensive strategy for the development of a single European digital space.

The growing demand for IT services globally makes technology both a catalyst for growth and a reliable protection against competitors. For example, many experts believe that Polish programmers are among the Top 3 in the world. Poles are valued for the high quality of their work, their quick adaptation to change, and high productivity.

The added value of the research is that, based on the Markov chain simulation, transitioning was found for ICT staff with different educational attainment levels, and the employment rate forecast up to 2025 was created. It was established that in the next five years, the pace of personnel transitioning from being low- to high-skilled will increase. The highest employment growth of ICT staff will occur by 2023, after which, employment growth will slow. Overall, by 2025, the employment rate of ICT staff will increase by 64% compared to 2018, and given the availability of easily available training resources, growth will be largely driven by the increasing employment of middle- and low-skilled ICT staff.

The growing demand for a labor force of medium and low qualifications will be primarily attributed to personnel polarization and causally related to the development of ICT and the adoption of innovations in enterprises, both at the government and enterprise levels. The main obstacle to employment growth through digitalization is the global economic crisis based on different factors. In case of an economic crisis, enterprises will urgently need to restructure the technological aspects of their operations and significantly retain personnel with different educational attainment levels.

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Prognozowanie stopy zatrudnienia w obszarze ICT w Unii Europejskiej

Zakorzeniona w ostatnim dziesięcioleciu tendencja do wdrażania technologii informacyjno-komunikacyjnych w przedsiębiorstwach UE spowodowała wstrząsające zmiany na rynku pracy. Ponieważ zapotrzebowanie na personel ICT rośnie, nadal istnieje potrzeba stworzenia kompleksowej strategii skutecznego zarządzania specjalistami ICT na potrzeby restrukturyzacji przedsiębiorstw. Celem badań jest identyfikacja procesów transferu pomiędzy nisko- i wysoko wykwalifikowanym personelem ICT oraz przewidywanie wskaźnika zatrudnienia w dziedzinie ICT do 2025 r. W badaniach wykorzystano łańcuch Markowa jako metodę analizy. W OPARCIU O dane statystyczne dotyczące wskaźnika zatrudnienia personelu ICT według poziomu wykształcenia opracowano model łańcucha Markowa, który opisuje procesy personelu ICT o różnym poziomie wykształcenia. Do analizy wykorzystano dane z okresu 2005–2019 do zbudowania prognozy ze względu na brak najnowszych informacji. W efekcie udowodniono, że przy pomocy procesów digitalizacji stopa zatrudnienia pracowników ICT w 2025 r. wzrośnie o 64% w porównaniu z danymi z 2018 r. Badania potwierdziły, że personel ICT będzie bardzo potrzebny do 2023 r., a co ważne, zapotrzebowanie na pracowników o niskich i średnich kwalifikacjach będzie rosło, jak i na wysoko wykwalifikowanych. Stopa zatrudnienia w dziedzinie ICT będzie na wyższym poziomie w 2022 r., ponieważ sprzyjające warunki ekonomiczne dla przyjęcia ICT mu pomogą. Rosnące zapotrzebowanie na personel ICT o niskim i średnim poziomie kwalifikacji będzie zapewnione przez personel przenoszący procesy, przedsiębiorstwa i cyfryzację rządu. Największy wzrost zatrudnienia personelu ICT nastąpi do 2023 r., a w przyszłości wzrost zatrudnienia spowolni. Główną przeszkodą dla wzrostu zatrudnienia poprzez cyfryzację jest globalny kryzys gospodarczy. Wartością dodaną analizy jest prognoza, że największy wzrost zatrudnienia personelu ICT nastąpi do 2023 roku, ale po będzie mało miejsce spowolnienie wzrostu zatrudnienia. Główną przeszkodą we wzroście zatrudnienia poprzez cyfryzację jest światowy kryzys gospodarczy z różnych powodów.

Słowa kluczowe: wdrożenie ICT, cyfryzacja, zarządzanie zatrudnieniem, popyt na pracę, łańcuch Markowa