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# THE EFFECTS OF THE HIGHER EDUCATION-RELATED FACTORS ON DIGITAL SKILLS IN THE EUROPEAN REGION

Master Thesis

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## Abstract

The current master thesis aims to evaluate the impact of higher education on digital skills in the European region represented by 24 countries. In the research 6 factors were extracted from Eurostat and from European Tertiary Education Register. They are the percentage of people using the internet, the number of universities, the percentage of female graduates in ICT-related fields, the ratio of students to teachers and academic staff in higher education, and the percentage of the population aged 65 and over, and the region (whether a country belongs to the Western or Eastern region). Multiple linear model regression was used to answer the research question. The variables Internet use and age are positively correlated with digital skills, while the variables female graduates in ICT-related fields and the ratio of students to teachers and academic staff are negatively correlated. The number of universities and region are not significant for having digital skills in this case. In conclusion, the result shows, albeit with some limitations, that higher education has an impact on individuals' digital skills, which are essential in the 21st century.


*Keywords: Digital skills, Higher Education, multiple linear regression*


Käesoleva magistritöö eesmärgiks on hinnata kõrghariduse digitaalse oskuste kompetentse kahekümne neljas Euroopa Liidu riigis. Uurimistöös on käsitletud kuus muutujat, mis on saadud Eurostatist ja Euroopa kolmanda taseme haridusregistrist. Kontrollitavad muutujad on internetikasutajate arv, ülikoolide arv, IKT valdkonna naiste lõpetajate arv, üliõpilaste ning õppejõudude ja akadeemiliste töötajate suhe kõrghariduses, ning 65-aastaste ja vanemate osakaal Lääne ja Ida regioonides. Selleks, et leida vastust antud uurimisküsimusele võeti kasutusele mitu lineaarset mudeliregressiooni. Interneti ja vanuse muutuja on digitaalsete oskustega positiivse korrelatsiooniga, samas kui naissoost IKT-alase lõpetajate ning üliõpilaste suhe õpetajatesse ja akadeemilistesse töötajatesse on negatiivse korrelatsiooniga. ülikoolide ja regioonide arv ei ole antud juhul oluline. Tulemuste põhjal hüpotees osutus tõeseks, seega kõrgharidus 21. sajandil mõjutab üksikisikute digitaalseid oskusi.

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# 1. Introduction

Modern society has entered a new stage of global economic development, known as the "digital economy", characterized by extensive and profound computerization and digitalization of all aspects of human activity. This means that new skills are required for individuals in the changed world to lead a decent life. Digital skills are of the high importance in all spheres of human life because technologies and new devices now play an important role and people should take advantage of them to benefit both in their personal lives and at work. It is digital skills which are a set of skills that enable people to use digital devices with the aim of accessing and managing information efficiently (Deursen & Van Dijk, 2011). This concept will be used further in current research. Moreover, the Coronavirus crisis accelerated this digital transformation (Digital Skills, 2021). However, as technologies become more complex, the knowledge and skills to use them must also evolve. At this point, the question arises as to what factors influence the level of digital skills. Along with access to technologies and the internet, level of living and place of residence, education is also an important factor that affects the digital skills that can be acquired during the educational process. In addition, higher education is not a mandatory step in education and some people do not opt for a bachelor's degree or higher. However, this can have an impact on digital skills.

There have been no studies that would cover the topic of relationships between digital skills and higher education. After reviewing the relevant articles, the most prominent work in the field of digitalization in the European region is the work of Kinnunen et al., 2019. In the latter research, principal component analysis was used focusing only on the variables of various aspects of digitization in the European Union, not touching upon such factor as higher education or education in general (Kinnunen et al., 2019). However, first of all, the work does not include data about the higher education and secondly, a cluster analysis was used based on the Eurostat database. On the other hand, many articles in the field of higher education link the influence of digital skills and higher education (Hämäläinen et al., 2021; Iivari et al., 2020; Lacka et al., 2021; Magni et al. 2021). In some works, research on digital skills focuses on a particular country or area in Europe, for example, Romania (Lazar & Roman, 2021), the Netherlands (Deursen et al., 2011), Spain (Guzmán-Simón et al., 2017). Thus, there is no research that includes cross-country comparisons of the relationship between higher education and digital skills in the European region. Stemming from this gap

in the literature, the author formulates the following research question: *to what extent are the factors related to higher education linked with digital skills in the European region?* Exploring this connection is important for the further development of digital skills among the population in the region, as many jobs nowadays require people who can use laptops and other devices for their work. The findings of this thesis would help to identify the most relevant factors in higher education and fill the gaps in the study of indicators that influence digital skills and examine them in detail. Therefore, the aim of this thesis is to find out the relationships between higher education related factors and digital skills in the European region.

For the research the method of multiple linear regression is applied. 24 countries were selected, among which are Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Austria, Poland, Portugal, Romania, Slovakia, Finland, Sweden, Norway, North Macedonia. The assumption that internet use is positively related to digital skills was confirmed. However, the interesting result showed that female graduates in ICT fields and the ratio of pupils and students to teachers and academic staff have a negative influence on the level of digital skills. This result is contrary to the assumptions based on the previous works. The second unexpected outcome of this study was the relationship of age and digital skills which contradicts the assumption but supported in the literature. It shows the positive relationship assuming the fact that this variable represents the percentage of people aged 65 and above. The number of universities and region are not significant in this case.

The master thesis has the following structure of the work. Chapter 2 provides an overview of the work on the topic, showing the concept of digital skills and its relationship with higher education in the European region. Chapter 3 presents the empirical analysis of the thesis, the data collection, the rationale of the model and the variables. Chapter 4 summarizes the findings of the research, its limitations based on them.

## 2. Literature Review

In this section, the literature review will be divided into 2 main groups. The closer look will be given to the articles dedicated to:

1. what are the digital skills and how they are assessed;

2. what is higher education and its influence on the digital skills in the European region.

## 2.1.Definition of digital skills

The way how people work now has changed drastically due to technological changes, which also created new jobs (Soulé & Warrick, 2015). That requires people a certain level of digital skills in order to stay competitive at work and participate in social life as a citizen (Anderson, 2008). The importance of digital skills was also pointed out by Kuhlemeier & Hemker, 2007, who stresses that developing these skills is one of the educational goals.

However, many authors admit the value and paramount role of digital skills; there is no commonly used definition of this term yet. For example, Krumsvik, 2008 uses the terms digital skills and digital literacy as synonyms. Digital competency and digital literacy are the terms that are used by authors interchangeably with digital skills. Spante et al., 2018 in the result of the systematic review, comes to the conclusion that digital literacy is more commonly used, but the usage of the terms depends on the regions and the sphere of usage: academy or policy. Nevertheless, some research means that digital competency is a broader term than digital skills. Thus, Hämäläinen et al., 2021 writes that digital competence includes digital skills as well as knowledge about digital technologies and attitudes towards them. The same approach is used while determining the digital skills by Skov, 2016. Digital skills are part of the concept of digital literacy, which also includes knowledge and attitudes to the use of technologies.

The term "skills" is considered as the ability of a concrete or abstract employee to ensure the implementation of a specific professional activity, and in the general case, at a specific job position and at a specific time. Thus, skills are highly dynamic entities associated with a specific context or ecosystem of professional activities. In this connection, they have their own life cycle, directly related to the life cycles of the workplace and the employee himself (Sukhomlin et al., 2017).

According to Claro et al., 2012, previously, digital skills had a strictly technical orientation, while now they are transforming into “so-called content-related or higher-order skills”. Levy & Murnane, 2006 come to the conclusion that nowadays, only technical skills are not relevant in the 21st century because the world now requires solving more complex issues that are more likely related to the digital environment and usage of higher-order cognitive abilities. Nowadays, many people have advanced mobiles, computers/laptops and

access to the interne; however, possessing of these technologies is no longer an indicator of having digital skills because it is much important to take advantage of them for solving individual's problems both for personal and work reasons (Deursen & Van Dijk, 2011).

To sum up, in the author's opinion, there is a difference between digital skills on the one side and digital competency and literacy on the other one. Therefore, in this thesis, only the term "digital skills" will be used, which means the combination of knowledge, practices and skills in order to solve people's issues using the benefits of modern devices.

## 2.2. Assessment of digital skills

Several approaches exist in order to assess the digital skills of the population, notwithstanding the fact that there is no widely accepted among scholars definition of this term itself. Mostly various non-profit organizations aimed at identifying people's skills also include measuring digital skills (Lemke, 2002), (*ISTE Standards for Students | ISTE*, n.d.), (O'Connor et al., n.d.), (d'Haenens & Joris, 2021). Having developed the different frameworks for measuring digital skills, the authors aimed to include assessing these skills along with testing the general literacy of people. However, the approaches pursue different goals - d'Haenens & Joris, 2021 and *ISTE Standards for Students | ISTE*, n.d. aim to evaluate digital skills of only young people, while O'Connor et al., n.d. and Lemke, 2002 are to test ICT skills and modern skills of the 21st century that are necessary at study and work accordingly. So, depending on the objectives, the different methods are used.

The question of assessing digital skills includes what to assess and how to assess. It means what parameters and factors to include as well as the scale for evaluation. Moreover, the methods for this implementation should be developed.

As for the assessment of digital skills, there are 3 major methods of assessing the skills (Deursen et al., 2014). The most commonly used way is to survey people about their digital skills based on the self-assessment. However, people can mean and assume different terms, and the results will be biased. That is why the second method presupposes the performance tests when people are asked to perform some actions in the laboratory and are observed. In order to assess the high level of digital skills, people are asked for specific results while using the internet and devices. It enables the researchers to identify how people apply their knowledge and digital skills (Deursen et al., 2014).

Laar et al., 2020 in their research, support the performance-based assessment method claiming that self-reported surveys do not provide reliable information because some people can overestimate or underestimate their skills, for example, men tend to exaggerate their skills in comparison to women. One more disadvantage the of self-judgement method is that in the process of survey, when people should evaluate their abilities, people usually misunderstand the concepts, and therefore the results are biased due to different perceptions (Bunz et al., 2007; Hargittai, 2005).

When the test-based approach is used, the following indicators are used according to Vuorikari et al., 2016: Information and data literacy, Communication and collaboration, Digital content creation, Safety, Problem solving. Before this approach was introduced, which is mostly used by Eurostat, n.d.; Hargittai, 2002 aimed at checking only participants' capabilities of searching certain information. Another approach was introduced by Alkali & Amichai-Hamburger, 2004 whose goal was to assess skills related to digital literacy - photo visual, reproduction, information, branching, and socioemotional. In contrast, Deursen & Dijk, 2009 assessed skills of using the internet.

As for the international organizations, Korobeynikova, 2019 compares different approaches to assessing digital skills based on the OECD, European Commission, World Bank frameworks having from three to four levels scale, generally having the gradation from low or basic to intermediate to advanced.

Gladilina et al., 2019 and Gryaznov, 2020 provide three main areas of digital skills:

A. universal digital skills: familiarity with basic tools (such as office productivity software, image processing, cloud applications and content, and tools for creating web content);
B. creative digital skills cover all aspects of the previous model, adding more complex technical skills (video production, audio production, animation, programming);
C. disciplinary digital skills: disseminated across disciplines in a variety of ways that are appropriate for each learning context, such as business courses on human computer interaction.

In this research, the data about the level of digital skills include the individuals who have basic or above basic overall digital skills (Eurostat, n.d.), which gathering is similar to Vuorikari et al., 2016 framework because this is the recent and widely used approach for gathering data about digital skills. However, there might be a contradiction in the sense that people who study or studied IT- or ICT-related fields would have high digital skills, and that might cause subjective results.

## 2.3. Relationship between higher education and digital skills in Europe

Article 26 of the Universal Declaration of Human Rights (Nations, n.d.) says that "Everyone has the right to education". At the same time, 'The Bologna Declaration of 19 June 1999', n.d. regulates higher educational institutions and was designed to provide the "competitiveness of the European higher education system". According to Altbach et al., 2009, the main goals of higher education which is commonly represented by universities are teaching, research, and public service. UNESCO Institute for Statistics, 2012 identifies the levels of education which are called The International Standard Classification of Education. In line with the document, the ISCED levels 5 to 8 belong to higher education. Having been created by the United Nations International Family of Economic and Social Classifications, this classification is also used by the European statistics in order to present more precise information in response to the levels of education. Later, in the empirical part of the thesis, the author will use the data related to ISCED levels 5 – 8 because this research is focused on the effects of tertiary education. In 2013, detailed information about the fields of education was introduced in the ISCED Fields of Education and Training classification (ISCED-F 2013). Code 06 stands for the group of programmes in Information and Communication Technologies related spheres; data of that category will be used further in the practical part as well.

With the globalization of the world today, education, like everything else, has become highly competitive. Every graduate student of the educational institution has to convince its client or customers that their skills are marketable, that their engineering or technologies are the latest and of the finest quality available anywhere in the world (Dahiya, 1996). Education that provides both an effective and efficient certificate system and delivers knowledge to society will help to take the advantages of globalization and let the graduates stay competitive in that world.(Maurya & Srivastava, 2020)

However, there is an issue that universities fail to prepare the students with the necessary work skills. Commission of the European Communities raises the problem of "parallel universes" which is reflected in the discrepancy of the business needs in the sphere of digital skills and supply of the government education systems. The reason for that issue is that many universities have to "keep up" (Selwyn, 2017) with technological transformations and the skills of both professors and students drop behind (Davies et al., 2017; Selwyn, 2017). Therefore, the educational programmes should be designed in a way that the outcomes

of learners meet the expected learning outcomes (Commission Of The European Communities, 2007). Due to this, the question of the importance of the higher education over the experience arises (Weiss et al., 2014).

Higher education institutions should pave the way for students so that learning new digital tools in the future would be intuitive. Pirzada & Khan, 2013 point out that higher education is positively related to digital skills. Digital literacy will become a must-have skill in the workplace, and all learners will need a high degree of digital skills to get a job, keep it, and earn a promotion.(Gryaznov, 2020)

Torres-Coronas & Vidal-Blasco, 2015; Monteiro & Leite, 2020 and Volungeviciene et al., 2020 admit that the document of the European Parliament about Key Competences for Lifelong Learning European Reference Framework identifies digital skills and their improvement through education as crucial for people's wellbeing to have these skills at least at the basic level. But according to the Digital Economy and Society Index (DESI), 4 out of 10 adults and every third worker in Europe does not have even basic digital skills (*Digital Skills and Jobs | Shaping Europe's Digital Future*, n.d.). In order to promote knowledge and skills in the digital sphere, in 2020, the EU developed a new Digital Education Plan for 2021. It aims to achieve the goal of 70% of the population aged 16 to 74 year old to have at least basic digital skills by 2025. The methods for implementing this goal will be based on the lessons learned from the Coronavirus crisis that triggered the massive usage of technologies in education and training as well as on the development of the education and training systems in order to meet the needs in digital skills (*Digital Skills*, 2021). Due to the Coronavirus pandemic, the demand in many non-ICT jobs that now require digital skills has increased. The effective use of these skills helps both workers and organizations that have to adapt to new conditions of work. For example, the retail sector, business and clerks, tourism moved their work to the digital environment. So grew the demand for skills in order to maintain the work of the organizations. Now, 28% of Europeans buy groceries online in comparison to 18% before the Coronavirus pandemic. It is more likely that such a way of life remains, and it means that digitalization will increasingly demand new jobs and tasks and, therefore, new digital skills. In this reality, access to education should be improved so that old citizens, where the gap in digital skills is observed, could have the opportunity to freely access learning and receive help from teachers in digital competence (*Digital Skills*, 2021).

The influence of the following factors related to higher education will be discussed: gender, usage of ICT, digital skills of the teaching staff, geography, age and level of education.

*GENDER*

França & Marques, 2021 highlight that the gender digital divide is a problem for the European community because it prevents women from building careers in the ICT sector. Because of that gender issue, girls are discouraged to develop their digital skills. As a result, there is a problem to meet market demand in terms of digital skills. However, the crisis showed that female students in Portugal performed better results of being involved in remote learning via digital technologies. The authors suggest creating an environment to attract more female students so that they could improve their digital skills in higher education.

In the research of Torres-Coronas & Vidal-Blasco, 2015, the variable of sex is not statistically significant except for indicators in Online communication, Social networks and Legal and network security aspects where female students show better results. The reason can be that women are better at social networking (Moghaddam, 2010), which is why their level of competence is better in these areas. For example, Tondeur et al., 2010 discover that the internet is used by women more for social reasons. At the same time, men use the internet more for instrumental and recreational purposes. However, in the studies of Matzat & Sadowski, 2012 men had been showing the growth in digital skills for the seven months of the research more rapidly than women which means that gender plays a role in the level of digital skills. On the other hand, responses given by male and female students are presented and show that both have digital skills in searching the information and its exchange and communication. (Monteiro & Leite, 2020). Apart from it, the Commission's study Women in the digital age (2018) shows that in the ICT sector, there are fewer women than men – 24 women out of 1000 graduate with major in the ICT field of study. Because of the low representation of women in this sphere, the European economy fails to receive annually €16 billion GDP(*Women in Digital*, 2014).

*USAGE OF ICT*

The research indicated the relation in both sides between the access to ICTs, their usage and digital skills (Mok & Leung, 2012). Youssef et al., 2013 point out that active usage of ICT leads to improvements in digital skills. Especially, it is important while learning in higher education institutions through interaction with technologies when the advantage of the latter is taken. Consequently, active and constant work with ICT contributes much to improving digital skills.

Bet et al., 2014 and Vekiri, 2010 agree that increased access to ICT and computers directly influences the level of digital skills. However, access by itself does not mean that

people would have excellent digital skills. Lee et al., 2015 and Deursen & Van Dijk, 2011 discuss that the level of education of internet users is important. Those with a low level of education in comparison to users with higher education degrees are prone to spend more time online playing games and entertaining. All in all, nowadays, there is more or less equal access to the technologies in the world, and the problem is to benefit from using them (Volungeviciene et al., 2020), and thus to enhance the digital skills.

So, there is a strong relationship between the usage of the internet and digital skills. The more often and regular the internet is used by a person, the more advanced skills a person learns. (Matzat & Sadowski, 2012)

### *DIGITAL SKILLS OF THE TEACHING STAFF*

Monteiro & Leite, 2020 come to the conclusion that the level of digital skills teaching staff has an effect on the digital skills of their students. It was highlighted that rapid digitalization and distance learning was unexpected for both parties. The authors propose to create the conditions on the basis of the universities for lifelong learning in order to eliminate the problem related to developing digital skills in case of new digital transformations.

The results of Hämäläinen et al., 2021 show that older teaching employees have weaker digital skills admitting the fact that these skills are important for their future professional development. So, people of different age are open to digital knowledge, but there is a difference in their background in this field.

### *GEOGRAPHY*

Although access to digital technologies is not equal yet, which also has an impact on the digital skills of people living in a particular area, it is due to the geographical location. At the level of any country, there is a discrepancy in access to the internet in the cities rather than in rural areas (Volungeviciene et al., 2020). For example, the Lithuanian Department of Statistics, 2017 presents the following numbers: 73,2% of the population in the cities could access the internet, while only 65,7% of households enjoyed access to the internet in rural areas.

However, in the scale of the European region, another division is represented by Kinnunen et al., 2019 that shows geographical differences in Europe. The authors demonstrate that Nordic and Western countries have advantages in digitalization compared to Eastern and Central Europe. The map below (Figure 1) reflects the percentage of people with basic digital skills by countries and proves the study of Kinnunen et al., 2019.

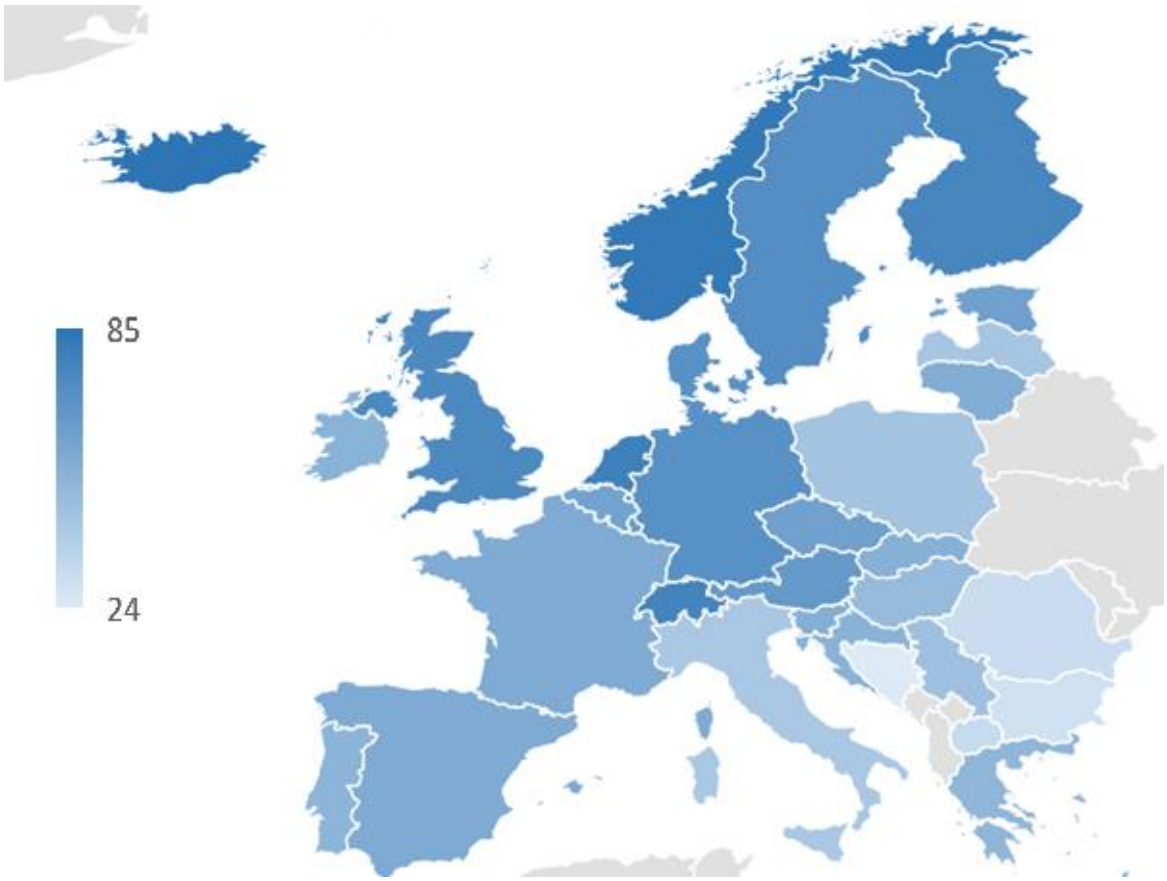


Figure 1 - *Percentage of individuals with above basic digital skills in 2019, the author's own visualisation based on Eurostat data (Eurostat, n.d.)*

*AGE*

In different research papers, the variable of age has both positive and negative correlation with digital skills as well as is not sufficient. Thus, Monteiro & Leite, 2020 conclude that in their research the age is not significant for the evaluation of digital skills. Marco et al., 2012 stress that young people are better at using the internet while old respondents have lower digital skills. Additionally, Volungeviciene et al., 2020 concludes that in Lithuania, the older the group, the less share of their members use the internet (98% of all 16 to 24 years old in comparison to 34% at the age of 65-74), which means that their digital skills are less developed. In contrast, Eshet-Alkalai & Chajut, 2009 state that there is a negative effect of age on digitals skills, meaning that older people (30-40 years old) can better increase their digital skills than young people. However, Matzat & Sadowski, 2012 claim that age is correlated with a lack of digital skills for older people because it is hard to evaluate them, and therefore older adults are an indicator of indirect proof of the lack of digital skills.

*LEVEL OF EDUCATION*

For measuring digital skills among the students, Pagani et al., 2016 use in-depth standardized test gathered by means of ad hoc surveys as Deursen et al., 2014 and van Laar et al., 2020 suggest. The authors conclude that digital skills influence education positively. They also add that the results depend on students' characteristics. However, Matzat & Sadowski, 2012 note that educational level does not play a role in the acquisition of digital skills. However, the way of getting the knowledge is significant. The authors emphasize that the self-learning approach that is commonly used in higher education institutions( Garrison, 1997) is useful for developing digital skills, even for those who have a low level of them. Ingen & Matzat, 2018 recognize a positive effect of education on digital skills with a correlation of 0,4.

Based on the literature review above, the following factors in higher education influence the digital skills in the European region:

- Gender;
- Internet usage;
- Level of education;
- Age;
- Digital skills of the teaching staff.

All in all, the controversial influence of gender and age on digital skills is discovered in the literature. In some research, it is insignificant, while other papers show both positive and negative influence of these factors. At the same time, usage of ICT, level of education and digital skills of the teaching staff have positive relationships with digital skills. Location of people has an impact as well.

# 3. Empirical analysis

In the research, an empirical analysis will be performed based on the statistical data regarding the European region. In order to define the factors that play the role or have no influence of the digital skills in Europe, multiple linear regression model will be used.

## 3.1.Data collection

Since the research concerns the European region, the data for analysis is collected from the Eurostat database https://ec.europa.eu/eurostat/data/database and from European Tertiary Education Register (ETER) https://www.eter-project.com/#/search where all the

related to educational bodies information collected for the European region. The data covers the period of 2019 year because, first of all, it is the last year before the Coronavirus crisis. The author assumes that the pandemic situation might have exogenous factors, and the results will be adjusted to the new reality. Further research is suggested to carry out in order to evaluate the impact of Coronavirus on the digital skills of the population. Secondly, the most recent update regarding digital skills data in Europe was done in 2019. For the research 24 countries were chosen. They are Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Austria, Poland, Portugal, Romania, Slovakia, Finland, Sweden, Norway, North Macedonia. Although datasets include more countries, the listed above ones have the complete data according to each variable. Since the data is collected from different sources and various approaches were used for its collection, some of the variables lack data. So, due to that limitation, the 24 countries were eventually selected.

## 3.2. Variables and regression model

Based on the research question of obtaining higher education and its influence on digital skills of people in the European region, the following variables are chosen and presented in Table 1:

- *internet_use* has an impact on digital skills. According to Deursen & Van Dijk, 2011, people who have access to the internet and use it have better digital skills. In Wales (*Internet Use and Digital Skills (National Survey for Wales)*, n.d.) the results show that more highly qualified and educated people use a variety of internet activities. So, the relationships between internet use and digital skills are traced. Although in the literature review part, the relationship of access to the internet and ICT is discussed, it does not mean that those who have it would use the internet and ICT. Therefore, it is the internet use which is chosen for the research because it is a more precise indicator rather than access. The data is taken from (*Database - Eurostat*, n.d.) and shows the percentage of individuals who used the internet in the last 12 month.
- *nr_universities* is thought to have a positive impact on digital skills because the universities teach their students to various skills that are needed in the labour market, including digital skills (Jørgensen, 2019). The digital skills of the teaching staff are discussed in the literature review. However, it is hard to

measure them in such a scale as the whole European region. Moreover, it would be hard to separate the digital skills of the professors from the rest of the population because these results might be in two groups and lead to controversial results. Instead, the indicator of the number of universities in a country is used. The data is taken from (*ETER*, n.d.) and shows the number of universities in a country.

- *grad_women _ICT* – women are less represented in ICT sector because the majority of graduates in this field are men. So, due to the lack of women with digital skills, the country's GDP is less than it could be *(Women in Digital, 2014).*
- *ratio* – ratio of pupils and students to teachers and academic staff. The less the group of students and the more the professor staff, the more effective knowledge and skills are obtained by students.
- *age* – the older population is less involved in digital technologies. So, the older people live in the country, the less likely the level of digital skills would be high. This variable represents the proportion of the population aged 65 and over and is taken from (*Database - Eurostat*, n.d.).
- *region* – counties were divided into two categories – into West and East. Since the development of these regions is not on the same level, it might also influence the digital skills of their population (Global a Survey Countries).

It should be noted that the data used for these variables concerns tertiary education (levels 5-8) according to the UNESCO classification, which is also used in Europe.

Eventually, in the research for the model, the following independent variables were chosen:

Table 1

*Independent variables*

| Independent variable | Description | Time frequency | Information society indicator | Unit of measure | Individual type | Source |
|---|---|---|---|---|---|---|
| *internet_use* | Individuals - internet use | Annual | Last internet use: in the last 12 months | Percentage of individuals | All Individuals | Eurostat |
| *nr_universities* | Number of universities | - | - | Number | - | ETER |
| *grad_women _ICT* | Female graduates in ICT related fields | Annual | Women who graduated in ICT related fields and obtained tertiary education (levels 5- 8) | Percentage of individuals | Females | ETER |
| *ratio* | Ratio of pupils and students to teachers and academic staff | Annual | Individuals involved in tertiary education (levels 5-8) | Rate | - | Eurostat |
| *age* | Proportion of population aged 65 and over | Annual | Proportion of population aged 65 years and more | Percentage of individuals | All individuals older 65 | Eurostat |
| *region* | West<br>East | - | - | Dummy variable | - | Global a Survey Countries |

Source: Author's own calculations

The presented above are observable variables. Those variables that are hard to observe and get the relevant information are put into the "error term" ($\varepsilon$)

The dependent variable is *ind_dig_skills* - Individuals' level of digital skills. The unit of measure is the percentage of individuals. The data is collected annually and represents all types of individuals. In this thesis, the data about digital skills will be used based on four areas (Information skills, Communication skills, Problem solving skills and Software skills) *(Database - Eurostat, n.d.),* excluding Safety according to Vuorikari et al., 2016 because this is a unified way of measuring digital skills of people in Europe based on test performance, not self-surveys which can bias the results (van Laar et al., 2020).

From Table 2, the mean value for Individuals' level of digital skills is 55,42, which means that more than a half of the population has at least a basic level of digital skills. At the same time, the mean for internet usage is 86,96. The conclusion is that not all people who use the internet can perform basic tasks using the technologies.

Table 2

*Descriptive statistics of the datase*

| Statistic | Min | 1st Quartile | Median | Mean | 3rd Quartile | Max |
|---|---|---|---|---|---|---|
| *ind_dig_skills* | 29 | 44,75 | 56 | 55,42 | 65,25 | 83 |
| *internet_use* | 71 | 82 | 86 | 86,96 | 91,75 | 99 |
| *nr_universities* | 2 | 32,75 | 46 | 88,96 | 74,25 | 390 |
| *grad_women _ICT* | 0,5 | 1,775 | 2,1 | 2,633 | 3,275 | 5,8 |
| *ratio* | 4,4 | 11,45 | 13,95 | 14,13 | 16,38 | 22,5 |
| *age* | 14,1 | 18,3 | 18,3 | 19,11 | 20,38 | 22,9 |
| *region* | | | | | | |

Source: Author's own calculations

In the current research, the hypothesis that influence of the education-related factors is present, whether they jointly impact digital skills. Thus, the hypothesis is formulated (1):

$$H_0 : \beta 1 = \beta 2 = \beta 3 = \beta 4 = \beta 5 = \beta 6 = 0$$
$$H_1 : \text{at least one variable is not equal to 0} \quad (1)$$

The population model is the following (2):

$$ind\_dig\_skills = \beta0 + \beta1 internet\_use + \beta2\ nr\_universities + \beta3\ grad\_women\_ICT + + \beta4 ratio + \beta5 age + \beta6 region + \varepsilon \quad (2)$$

where β0 is intercept, β1, β2, β3, β4, β5, β6 are parameters, $\varepsilon$ is an "error term".

However, before discussing the results, the model should be checked according to linear regression assumptions. In order to decide whether the obtained results are reliable, the Multiple Linear Regression Assumptions should be checked.

### 3.3. Checking Linear Regression Assumptions

There are the basic assumptions that are usually applied in order to to ensure that the models used are appropriate for the data being studied (Demos & Salas, 2017; Casson & Farmer, 2014).

Assumption №1: The model should be linear in parameters.

It means that the parameters $\beta_i$ have to be linear, although the variables are possible to be, for example, squared or taken from logarithm. In the current research, this assumption is met because model (3) does not contain non-linear parameters.

$$ind\_dig\_skills = \beta0 + \beta1 internet\_use + \beta2\ nr\_universities + \beta3\ grad\_women\_ICT + + \beta4 ratio + \beta5 age + \beta6 region + \varepsilon \quad (3)$$

Assumption №2: There is no perfect collinearity in the data.

First of all, in order to avoid such phenomena as perfect collinearity which can cause dependence between the independent variables in the research, the correlation between our explanatory variables is checked. The assumption is that the independent variables do not have perfect collinearity (this means that in our data there is no independent variable that can be expressed as a linear function of any other independent variables). Correlation coefficient lies between -1 and 1. So, when there is a strong negative correlation, this means that every time one variable increases, other variable decreases. Zero means that there is no correlation at all between the two variables. A strong positive correlation means that every time one variable increases, another one also increases.

The results show that both positive and negative correlation is presented between the variables in Figure 2. However, all of the values do not exceed |0.34|. For example, *age* is negatively correlated with other *internet_use*. The explanation to this effect might be that the more people (the bigger percentage of the population) aged over 65 the less likely they use the internet.

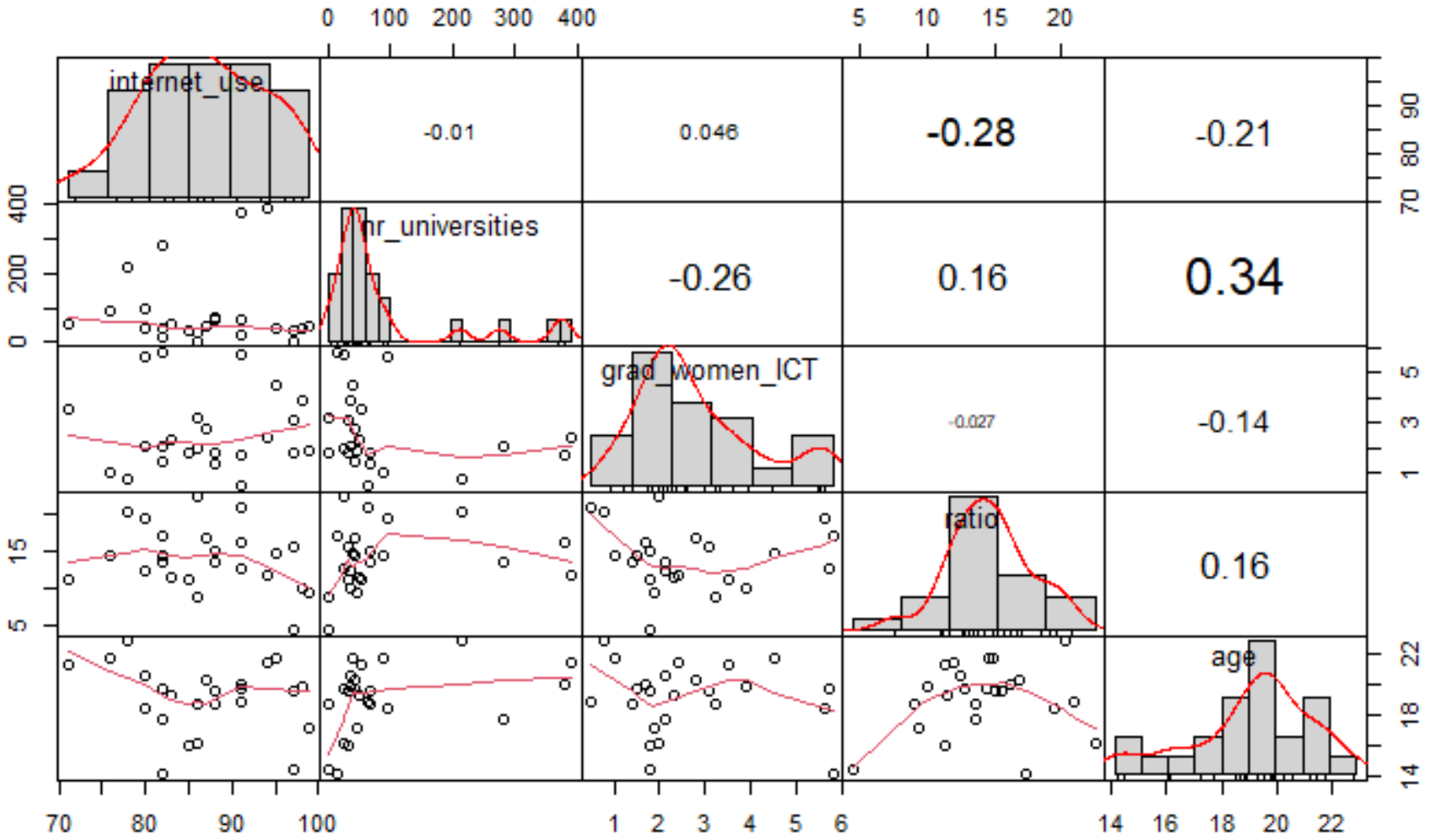


Figure 2 - *Correlation between independent variables*

Source: Author's own calculations

One more method to check the multicollinearity between the explanatory variables in linear regression is to use the Variance inflation factor (VIF). The result should be within the range from 1 to 5, which shows the moderate correlation among the variables and proves that there is no violation of the assumption. The results presented in Table 3 do not exceed the threshold, which means that there is no problem with multicollinearity between the independent variables in the model.

Table 3

*VIF*

| internet_use | nr_universities | grad_women_ICT | ratio | age | region |
|---|---|---|---|---|---|
| 1.940930 | 1.224566 | 1.094977 | 1.142626 | 1.476444 | 2.024741 |

Source: Author's own calculations

The tests show that this assumption is met.

Assumption №3: The values of the residuals are independent of each other.

In order to check this assumption, a Durbin-Watson test should be undergone. This test is used for the detection of autocorrelation in the residuals in our model.

The following hypothesis is considered:

$H_0$ (null hypothesis): There is no autocorrelation among the residuals.

$H_1$ (alternative hypothesis): The residuals are autocorrelated.

Thus, p-value is equal to 0.928 > 0,05 (Table 4). So, we cannot reject $H_0$ and conclude that our residuals are not autocorrelated.

Table 4

*Output of the Durbin-Watson test*

| lag | Autocorrelation | D-W Statistic | p-value |
|---|---|---|---|
| 1 | -0.03936387 | 2.016926 | 0.928 |

Alternative hypothesis: rho != 0

Source: Author's own calculations

The test shows that this assumption is met.

Assumption №4: The variance of the residuals is constant.

In order to check heteroskedasticity, Breusch–Pagan test is used. Heteroscedasticity shows the dependence of the residual distribution on the values of the explanatory variable. It

violates the assumption and, therefore, we should have homoscedasticity when residuals are distributed with equal variance at each level of the independent variable. While performing Breusch–Pagan test, we state the following hypothesis:

$H_0$ is that there is homoskedasticity (equal variance distribution)

$H_1$ is that there is heteroskedasticity (not equal variance distribution)

The results of Breusch–Pagan test show a p-value = 0.7137 (Table 5). It means that we do not reject the null hypothesis, and we do not have problems with heteroscedasticity in the model.

Table 5

*Output of the Breusch–Pagan test*

| studentized Breusch-Pagan test | | |
|---|---|---|
| data: model | | |
| BP = 3.7258 | df = 6 | p-value = 0.7137 |

Source: Author's own calculations

In addition to it, both Figures 3 and 4 shows relatively constant distribution of residuals accross the horizontal line which also means that visually we have the case of homoscedasticity. (The red lines in the graphs indicate the trend of the residuals, and it should be flat with no pattern to be traced. In our case, the red line is almost flat, and the residuals are spread constantly).

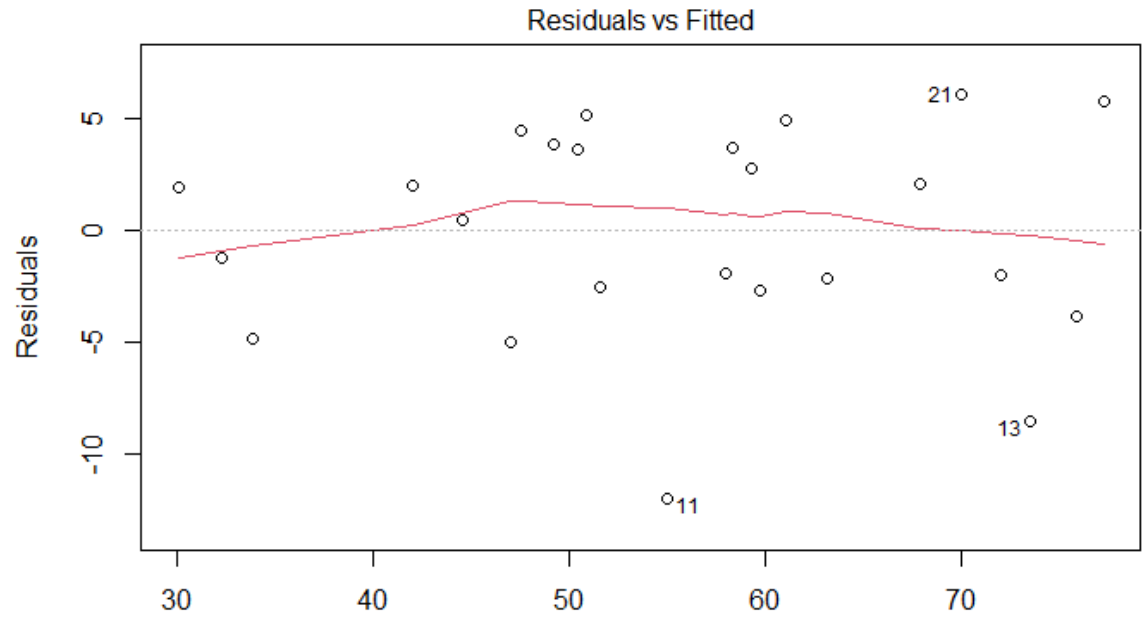


Figure 3 – *Distribution of the residuals*

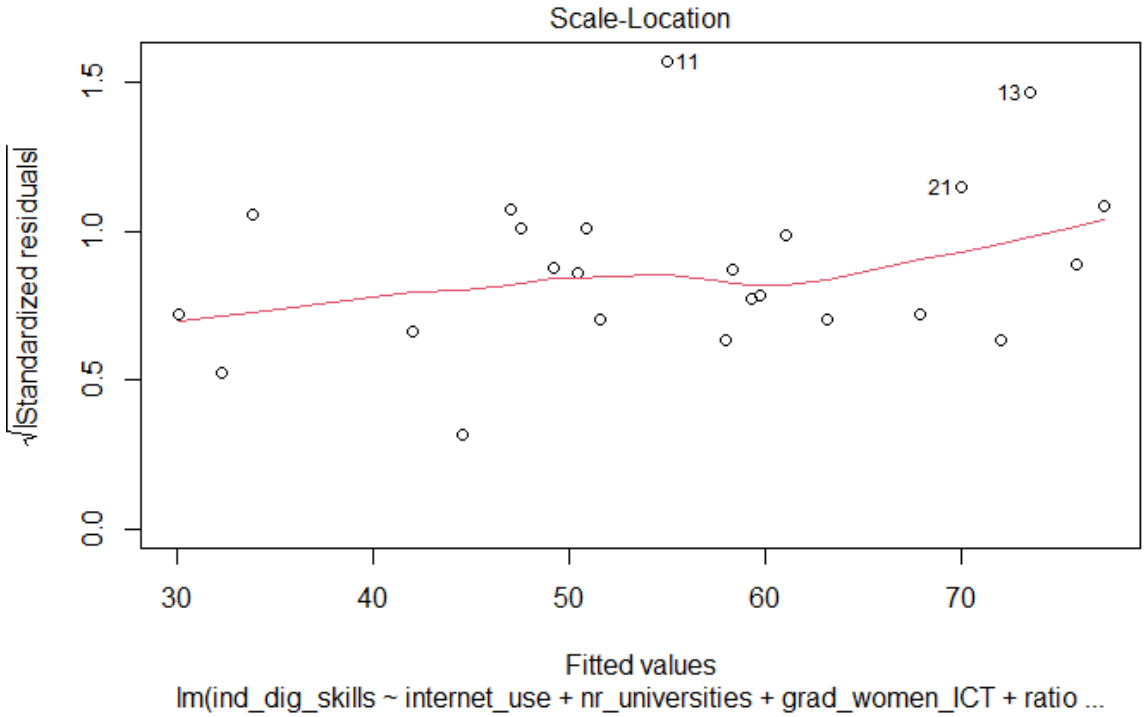


Figure 4 - *Distribution of the standartised residuals*

The test shows that this assumption is met.

Assumption №5: The values of the residuals are normally distributed.

For checking this assumption, the P-P plot is suggested to build. Ideally, all the dots should be on the diagonal line. However, in our case, the deviations are observable (Figure 5) but not critically. The model suggested that the assumption of normality of the residuals may have been violated. However, as only extreme deviations from normality are likely to have a significant impact on the findings, the results are probably still valid.

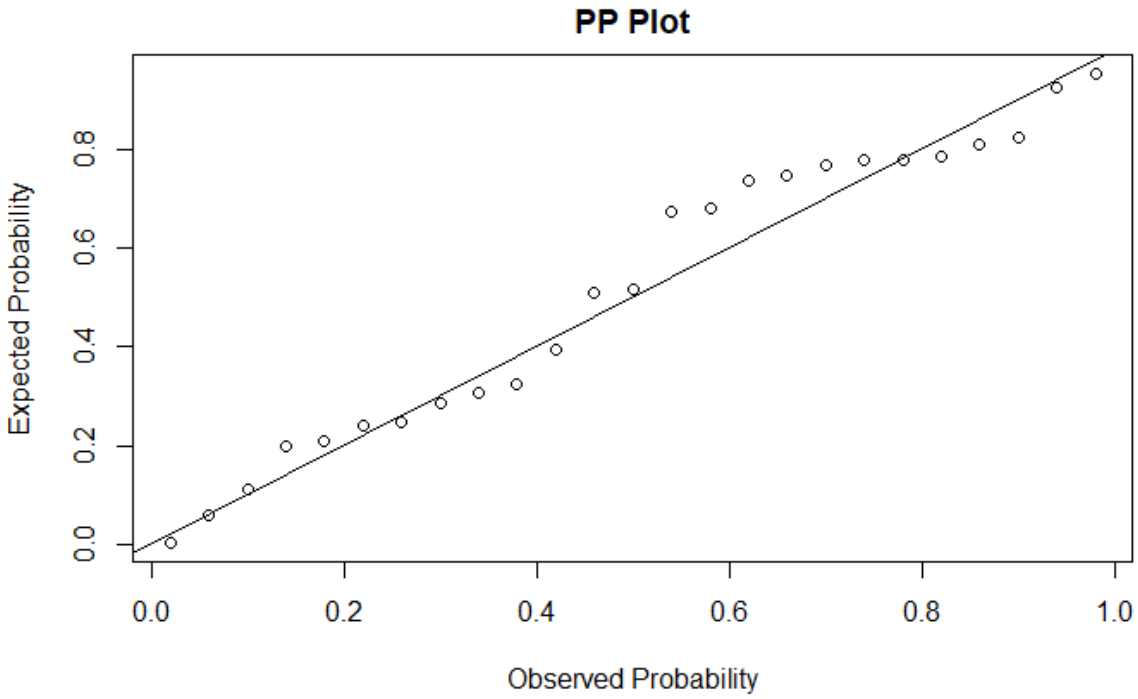


Figure 5 – *PP-plot*

In order to make sure that this assumption is not violated, Shapiro-Wilk test is performed.

$H_0$ : The sample is normally distributed

$H_1$ : The sample is not normally distributed

The result of the test (Table 6) shows that p-value > 0,05. Thus we cannot reject the null hypothesis, and the values of the residuals are normally distributed in this research.

Table 3

*Output of the Shapiro-Wilk test*

| | |
|---|---|
| Shapiro-Wilk normality test | |
| data: model$residuals | |
| W = 0.9304, | p-value = 0.09953 |

Source: Author's own calculations

The graph shows that this assumption is not fully met.

Assumption №6: There are no influential cases biasing the model.

For checking this assumption that there are no outliers that might violate the results of the model, Cook's Distance graph is built (Figure 6). In the graph, the dot 13 lies between 0,5 and 1 thresholds (Cook's distance that indicates the critical borders for the outliers on data). However, the values that are under 1 should not be seen as the ones that influence the model.

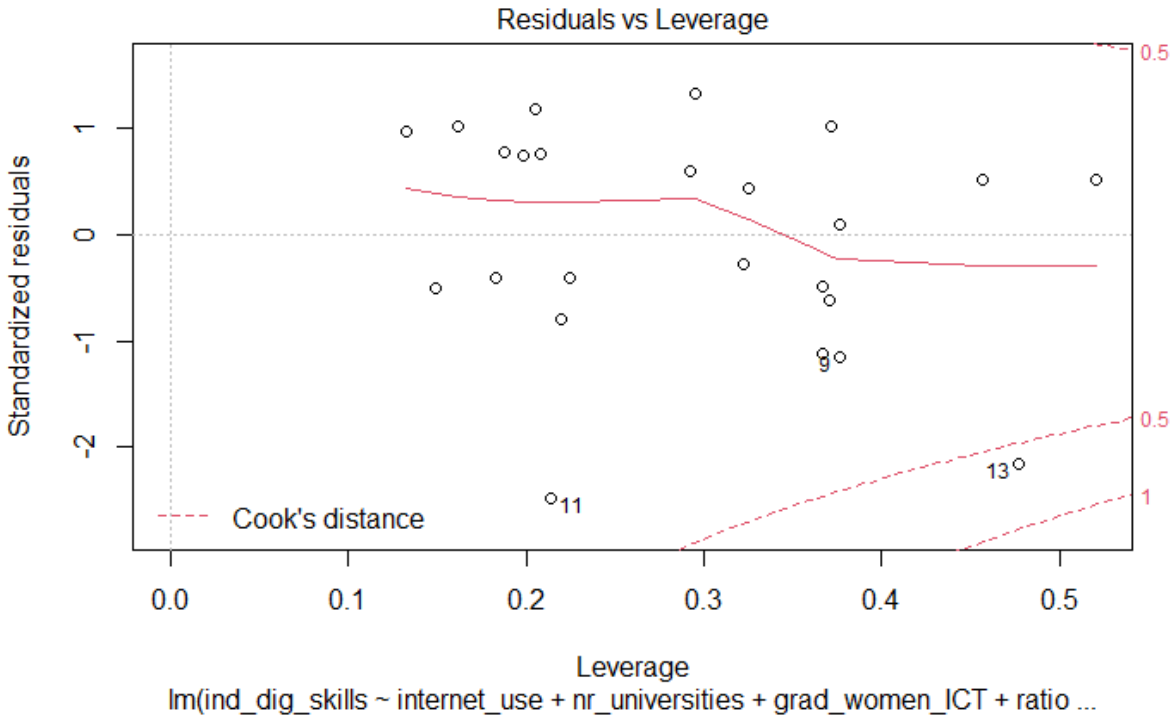


Figure 6 - *Cook's Distance graph*

The graph demonstrates that the assumption is met.

To sum up, assumptions 1-6 are checked and met except for the only one that can be perceived as violated (Assumption №5) because the points on the plot have some deviations, although it is not drastic. Having met all these assumptions means that the collected data is relevant and correct for the current research. The results of the multiple linear regression are not biased but accurate. It also means that while answering the research question, the conclusions made based on the data and the model are correct.

## 3.4.Discussing the results

The results presented in Table 7 show the significance of the independent variable effects on the dependent variable. The overall result is that the whole model is statistically significant (2.566e-07 < 0,05). So, we reject H0, and it means that there is a relation between the higher education-related factors and digital skills. Moreover, the tests of the model are performed in order to check the assumptions about the data and model, and they show that it is reliable and trustworthy.

The intercept in the equation is statistically significant at 1% and negative, which means that having all the other variables equal to 0, the level of digital skills cannot be negative. Therefore, in this case, there is no meaningful explanation of the negative intercept. R-squared is quite high and accounts for 0,8915. That means the percentage of variance in the dependent variable can be explained by the independent variable. R-squared is equal to 89% in this study and means that 89% of the data fit the regression model. Adjusted R-square is slightly less and is 0,8533 or a little bit more than 85%. It means that we included the relevant variables that actually affect the dependent variable in our model. Otherwise, the adjusted R-square would be critically less.

The results are interpreted as follows: if x increases (decreases) by 1 unit, y increases (decreases) by βi units. For example, if *nr_universities* increases (decreases) by 1 unit, *ind_dig_skills* increases (decreases) by β2 units.

Table 7

*Regression Results*

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | -97.69168 | 24.83560 | -3.934 | 0.00107 ** |
| *internet_use* | 1.55122 | 0.21284 | 7.288 | 1.27e-06 *** |
| *nr_universities* | -0.01853 | 0.01143 | -1.621 | 0.12334 |
| *grad_women _ICT* | -2.20777 | 0.78851 | -2.800 | 0.01231 * |
| *ratio* | -0.64484 | 0.29154 | -2.212 | 0.04096 * |
| *age* | 1.75535 | 0.61111 | 2.872 | 0.01056 * |
| *regionWest* | 2.31011 | 3.18743 | 0.725 | 0.47846 |
| Residual standard error: 5.468 on 17 degrees of freedom | | | | |
| Multiple R-squared: 0.8915, Adjusted R-squared: 0.8533 | | | | |
| F-statistic: 23.29 on 6 and 17 DF, p-value: 2.566e-07 | | | | |

Source: Author's own calculations; Note: '*' p<0.05; '**' p<0.01; '***' p<0.001

The first independent variable, the internet usage, is significant at 0,1% and positively related to digital skills, as was previously discussed in the literature part. So, the literature supports this relationship (Matzat & Sadowski, 2012).

The variable of female graduates in ICT related fields is significant at 5% level and negatively correlated with digital skills. As it was stated in the literature review, the gender aspect is controversial. In the current research, an increase in female graduates would reduce the percentage of people with digital skills. Although in the previous studies, gender is matter, it has a different correlation with digital skills. Thus, in the literature, Matzat & Sadowski, 2012 it was proven that men are better in obtaining digital skills. Moreover, the research of Torres-Coronas & Vidal-Blasco, 2015 supports that women are better in tasks of Online communication, Social networks and Legal and network security aspects. However, Monteiro & Leite, 2020 argue that society would benefit from having more women in the ICT sector. The reason for such a negative correlation might be that the tasks used for evaluation of digital skills among the population are not aimed at social networking where women are good at.

The variable of ratio of pupils and students to teachers and academic staff is also significant at 5% level and negatively correlated with digital skills. This relationship with digital skills is not discussed in the literature part due to the lack of information and previous empirical research on this topic. On the other hand, it was assumed that the less the ratio (which means the fewer students and more teachers), the better students would be acquired digital skills. In the literature, it is suggested that the level of digital skills of the teaching staff has an effect on the digital skills of their students (Monteiro & Leite, 2020). In contrast, the current empirical research does not prove that.

The age variable was also differently correlated with digital skills in the literature. In the current research, the variable is significant at 5% and has a positive correlation. Since the variable stands for the proportion of the population aged 65 and over, it means that if we increase the number of old people, more people will have digital skills, at least a basic level. Similar results were received and proven by Eshet-Alkalai & Chajut, 2009, but the author claims that it is applicable for adults 30-40 years old.

The number of universities and region are not significant in this case. As of the first variable, its relationship with digital skills has not been presented in the literature. The reason might be that not the overall quantity of them but rather the professional orientation is more important, for example, the number of technical universities. Another assumption is to use an adjusted number of universities per certain number of people, i.e., 100 000 citizens.

As of region, the literature supports that it is matter (Kinnunen et al., 2019). However, the authors use the cluster method for evaluation, where the data is grouped according to a specific cluster consisting of certain countries. Additionally, the visual data based on the Eurostat source (Figure 1) shows that Eastern Europe has less percentage of the population with above basic digital skills. If the region variable was statistically significant, it would also show that Western European countries have more people with at least basic digital skills.

*Limitations of the Study*

During the research, several limitations were discovered that could be addressed in future studies. First of all, the major limitation of the empirical part was the lack of data for some countries. As a result, not all European countries could be included in the study. For example, Switzerland, Montenegro, Ireland, Iceland, Serbia, Bosnia and Herzegovina, Greece and Spain were not included in the analysis. The second problem is that the collected data refer to the period before the pandemic and does not reflect the current situation. Thus, the outcomes of this thesis can contribute to further research that sheds light on the specific mechanisms underlying the effects of factors related to higher education on digital skills.

# 4. Conclusion

This research aimed to analyse the influence of higher education-related factors on the digital skills of individuals living in the European region. The literature review covers the concept of digital skills and how they are measured. Then, the relationship between the higher education related aspects and digital skills was discussed. The following factors related to higher education were found to correlate with digital skills: the internet use, geography and digital skills of teaching the teaching staff. However, based on the literature, age and female graduates in ICT fields show dubious impact.

To answer the research question, the multiple linear regression model was built and tested under assumptions. Variables included the percentage of people using the internet, the number of universities, the percentage of female graduates in ICT related fields, the ratio of pupils and students to teachers and academic staff in higher education and the percentage of population aged 65 and over, and region (whether a country belongs to the Western or Eastern region). The internet use was found to have the most significant and positive effect, as well as the negative effect of the percentage of female graduates in ICT related fields, ratio of pupils and students to teachers and academic staff in higher education and the proportion of the population aged 65 and older on digital skills.

As a result, the model is not violated, and the data as well as the results of the model can be trusted. The result shows that the tested aspects have an impact on individual’s digital skills which are important in our modern world.

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