THE DETERMINANTS OF INFORMATION AND COMMUNICATIONS TECHNOLOGY SERVICES EXPORT IN CENTRAL AND EASTERN EUROPEAN COUNTRIES

by

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Date _____

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LIST OF ABBREVIATIONS

SSSU State Statistical Service of Ukraine

WTO World Trade Organization

ICT Information and Communications Technology

CEE Central and Eastern European

OECD Organization for Economic Co-operation and Development

IT Information Technology

R&D Research and Development

EU European Union

STEM Science, Technology, Engineering and Mathematics

FDI Foreign Direct Investments

GDP Gross Domestic Product

CHAPTER 1. INTRODUCTION

During the past few decades, there has been a rapid growth in technology sector around the whole world. Therefore, consumer's demand increased for ICT products and services. As a result, ICT service exports have become a very important part of international trade.

This trend is supported by recent World Trade Organization data (World Trade Report, 2019). Services sector is now indicated as the most dynamic component of international trade, with its significance continually growing. The services sector currently represents approximately 50% of global GDP on average, while developed economies leaning even more heavily on services (at around 75% of GDP). Developing economies are also witnessing a swift increase in the services share of GDP. Since 2005, there is reported that trade in services growth average rate of 5.4% annually, outpacing the trade in merchandise growth rate at 4.6% annually. Over the past decade, trade in ICT and R&D services has grown particularly swiftly. The WTO forecasts that trade in services could constitute 50% of total trade, by 2040, due to digitalization, reduced restrictions, and decreasing trade costs.

The rapid growth of the ICT services sector in CEE countries could be potentially explained by multiple reasons. First reason is the region's strategic location at the junction of Europe, Asia, and the Middle East, represents it as an attractive location for companies looking for global expansion. Moreover, the region's highly educated and skilled workforce, particularly in computer science, engineering, and mathematics fields, has made it an ideal location for firms seeking to develop new products and developed services. Also, the region's relatively low labor costs attracted companies that aims to decrease their operating costs.

Despite the multitude of opportunities provided by the ICT service sector in CEE countries, significant challenges persist. A key challenge lies in the sector's shortage of skilled professionals. Although the region generates ample STEM graduates, many lack the practical skills and experience sought by employers in the ICT service sector. Another

challenge stems from insufficient investment in ICT infrastructure in certain countries, which has limited the sector's growth potential. Given the ICT service sector's importance in CEE countries, understanding the factors influencing its growth and development is crucial.

To explore the factors shaping the growth and development of the ICT service export industry in CEE countries, we employ a rigorous, data-driven methodology. Our analysis integrates both quantitative and qualitative data, aiming for a comprehensive understanding of industry dynamics.

This study's findings do not only contribute to existing academic literature but also offer valuable insights for policymakers and stakeholders. These insights can inform the development of strategies and policies intended to enhance the growth of the ICT service sector in the region, fostering economic growth and prosperity.

This research aims to investigate the determinants of ICT service exports in Central and Eastern European (CEE) countries, with focus on two research hypotheses. The first hypothesis examines the effect of government expenditures on education and R&D expenditures on ICT services exports, while exploring whether this effect is stronger for EU member countries compared to non-EU member countries in the CEE region. The second hypothesis investigates the mediating role of skilled labor (enrolled students) and internet availability in the relationship between foreign direct investment (FDI) and ICT services exports.

Fixed effects panel data model estimator with interaction terms, mediation analysis, and lagged variables was employed to test two main hypotheses. Data from 14 CEE countries over 20 years (2002-2021) were obtained from the World Bank, Eurostat, and UNESCO Institute for Statistics databases, resulting in a balanced panel dataset. The chosen methodology offers several advantages, including the ability to account for time-invariant, country-specific characteristics, a focus on within-country variation, and an examination of the dynamics over time with lagged variables. This comprehensive approach provides robust evidence and insights into the factors affecting ICT services

exports in the CEE region, ultimately contributing to a better understanding of how to foster a conducive environment for growth in this sector.

Regression analysis yields the following key findings for the posed hypotheses:

1. Government expenditures on education positively impact ICT service exports, with a weaker and even negative effect in EU member countries compared to non-EU countries.
2. Internet availability does not play a mediating role in the relationship between FDI and ICT services exports, as well as evidence of a mediating role of skilled labor (enrolled students) is limited.

Analysis results suggest valuable insights and recommendations for various stakeholders: policymakers, businesses, and researchers. Policymakers should prioritize investments in education and ICT-related skills and support R&D in the ICT sector. Businesses should focus on attracting FDI to build or improve internet infrastructure and participate in public-private partnerships to develop local talent and innovation. Researchers are encouraged to explore additional factors affecting ICT services exports and further investigate the mechanisms underlying the relationship between FDI and ICT services exports, particularly in relation to EU membership.

CHAPTER 2. INDUSTRY OVERVIEW AND RELATED STUDIES

2.1. ICT trade overview

The ICT services world market is important for economic growth and development. It helps make more jobs and makes businesses more competitive. ICT services also plays critical role in businesses and governments digital transformation, so they can work more effective and efficient way, and able to quickly adapt to changing needs. The ICT services market is also crucial for global trade and businesses across borders. As businesses and governments use more digital technologies to operate in the modern environment, the demand for ICT services has become global and more diversified. Companies and countries are looking for the services from the best providers, no matter where they are created.

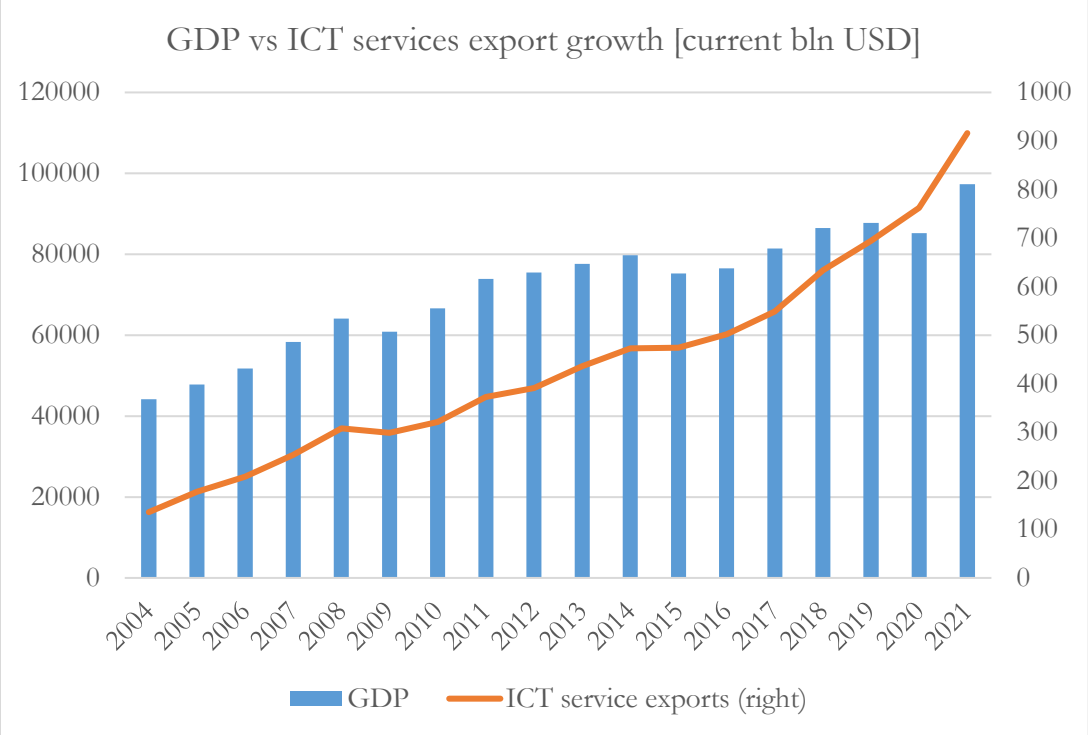
The global market for ICT services has rapidly grown a lot recently, because of the reasons mentioned previously. It is thought that the global ICT services market will be worth $1.3 trillion by 2023, growing at a 7.9% rate (Moore J., 2022). From 2004 to 2021, the global GDP has grown 120.4%, reaching 97,307 trillion USD in 2021. But during that same time, the ICT export grew even more - by 578.5%, making it worth 916 billion USD in 2021 (Fig. 1).

The market for ICT services can be split into two main categories: professional services and managed services. Professional services include things like software development, system integration, training services, and IT consulting. Managed services cover infrastructure management, network management, and security management services. Mostly, the global ICT services market is made up of professional services. The area that is expected to grow the most is the Asia Pacific, because countries like China, India, and Indonesia adopt and rely more on digital technologies. North America and Europe also have big markets for ICT services because they have many international companies and use advanced technologies.

The ICT services market is a highly competitive industry. There are different size companies presented on market, including multinational corporations and smaller firms

trying to get a bigger share of the market. Some of the major companies in the market are HP Enterprise, Accenture, IBM, TCS, Fujitsu, Infosys, and Capgemini. These companies try to beat each other by offering better service quality, lower prices, and creative solutions. One of the key trends in the market is the grown demand for the cloud-based services, as more companies want to use the advantages of cloud computing. New technologies such as the Internet of Things (IoT), machine learning, and artificial intelligence are also expected to make the global ICT services market grow more in the future.

Figure 1. GDP vs ICT services export growth

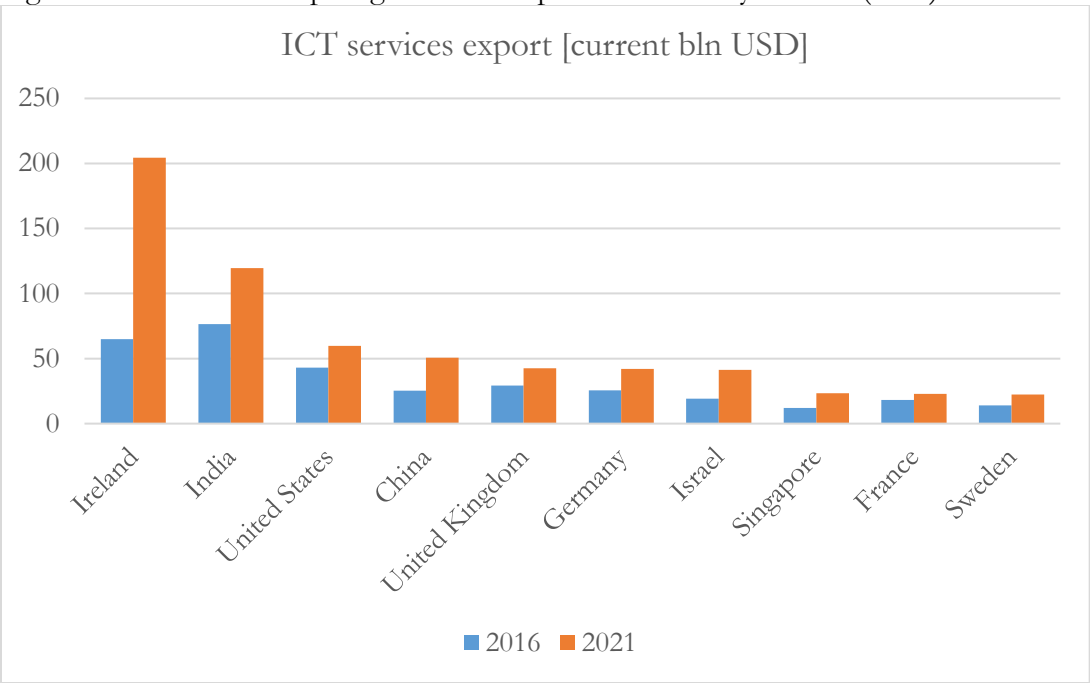


Source: World Bank data

The global ICT market has been demonstrating rapid growth during the last years. Gross ICT export reached 916 billion USD in 2021 which is 82,47% more than in 2016 and 145,57% more than in 2011. The best exporters for 2016-2021 analyzed period are Ireland (204 billion USD or 213,84% growth), India (120 billion USD or 55,8%),

USA (60 billion USD or 39,53% growth), China (51 billion USD or 104% growth), UK (43 billion USD or 48.2% growth).

Figure 2. ICT services export growth for top 10 countries by volume (2021)



Source: World Bank data

2.2. ICT industry sector overview

As per the findings of the "Future of IT Report" (2023), the ICT sector in the emerging Europe region displays a consistent upward trajectory in terms of both job opportunities and salary increments. Both the average salary and gross salary in the ICT sector have increased by approximately 50 percent since 2016, surpassing the rise in the consumer price index in most countries. On average, ICT specialists, comprising nearly three percent of the total employed population in 2021, earn roughly double the average salary. Among the countries in the region, Armenia exhibits the largest pay gap, while Slovenia has the smallest.

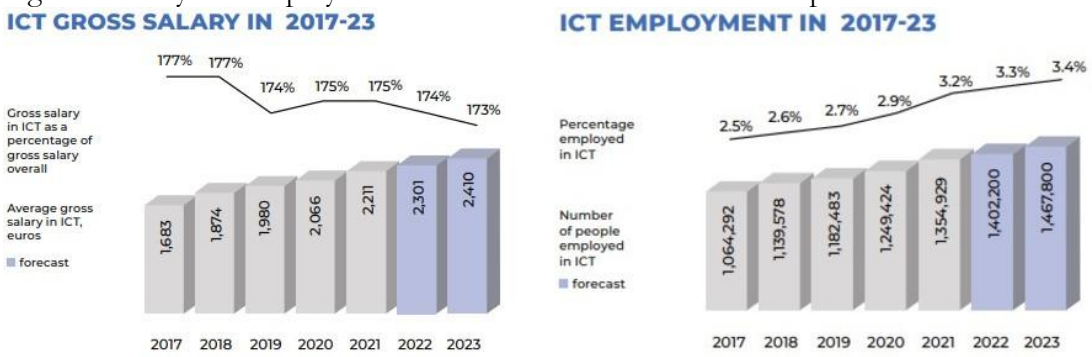
The significance of the ICT sector's role continues to expand, constituting around five percent of the regional GDP in 2021. For the first time, the value added by the ICT sector exceeded 100 billion euros, with approximately three-quarters of this value generated in Central Europe. On average, an ICT employee in the region contributes over 3,600 euros of value added per month, while the output per employee reaches almost 6,500 euros monthly. The export value of ICT services surged to 46.8 billion euros in 2021, a substantial increase from 38.8 billion euros in 2020. Remarkably, the sector demonstrated significant resilience to the effects of Covid-19, outperforming the linear trend based on pre-Covid data in 15 out of 23 countries in the region.

In 2021, IT sector in the following Central European countries such as Bulgaria, Croatia, Czechia, Hungary, Poland, Romania, Slovakia, and Slovenia demonstrated resilience by experiencing growth in both: value added and employment. The average salary in the IT industry exceeded 2,200 euros, surpassing Eastern and South-Eastern European countries, although still lagging behind North-Eastern Europe (Fig. 3). The salary gap within the IT sector continued to widen, reaching more than 18 percent in 2021. Unlike other subregions in emerging Europe, the wage disparity between the overall economies and the IT sector remained stable at around 75 percent. The growth in IT education mirrored the trend seen across emerging Europe, with a consistent increase in the number of IT students and graduates in recent years. The IT sector's contribution to GDP exceeded five percent, marking the highest figure in the region. However, based on trends in the IT services delivery, Northeast Europe is expected to surpass Central Europe in this aspect in the coming years.

Despite the challenges the ICT sector in the Eastern European region faced during the COVID-19 pandemic, and the Russian invasion of Ukraine, it has shown steady development, and is expected to maintain resilience. Preliminary data from 2022 supports this assertion. The region has witnessed growth in both ICT salaries and employment (Fig. 4), although the contribution of value added to GDP appears slightly lower.

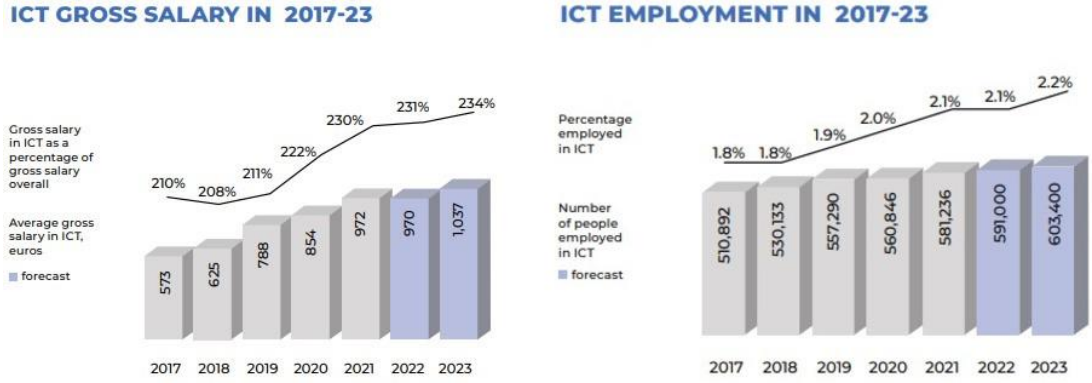
However, this does not disrupt the overall trajectory of sector development. It is worth noting that Eastern Europe region remains the second-largest IT hub, following Central Europe, with a substantial workforce of 581,000 ICT employees. While there has been a slight decrease in the number of ICT graduates in 2021, particularly in Ukraine, which serves as a prominent ICT education hub, the overall student enrollment continues to grow, reaching nearly 170,000 in 2021.

Figure 3. Salary and employment statistics for ICT in Central Europe



Source: Future of IT Report 2023, Emerging Europe

Figure 4. Salary and employment statistics for ICT in Eastern Europe



Source: Future of IT Report 2023, Emerging Europe

2.3. Related studies

Several studies, such as: Malik and Velan (2020), Sahoo and Nauriyal (2013), have investigated the determinants of IT software and service exports, particularly focusing on the case of India. Malik and Velan (2020) provided robust evidence of a stable long-run relationship among the variables considered. The empirical findings from the long-run model revealed that human capital, exchange rate, and external demand exhibited expected signs and significant impacts on IT exports across all levels of significance. Notably, "external demand exerted the most substantial and significant influence on IT software and service exports throughout the study period, followed by the exchange rate and human capital, respectively".

Sahoo and Nauriyal (2013) discovered compelling evidence of mutual causality between the GDP of high-income OECD countries and IT software exports, indicating a reciprocal impact where the GDP of these countries affects India's software exports and vice versa. Likewise, bilateral causality was observed between the openness index and software exports, suggesting that the level of openness has influenced software exports from India. The study revealed "a unidirectional and statistically significant impact of higher education enrollment on IT software exports, signifying that human capital, as measured by higher education enrollment, has influenced IT exports from India". Through regression analysis in first difference, it was found that "changes in the openness index, human capital, and the GDP of high-income OECD countries positively influenced changes in software exports from India". Overall, the study emphasizes the significant influence of factors such as GDP, openness, human capital, and the availability of skilled labor on software exports from India. These findings underscore the importance of implementing policies and making investments that promote economic openness, foster the development of human capital, and cultivate a favorable environment for the software sector, thereby supporting the sustainability and enhancement of India's software exports.

A recent study conducted by Zapata, Arrazola, and Hevia (2023) focused on analyzing the determinants of international trade flows of manufactured goods, particularly emphasizing the technological content of exports within OECD countries. The study utilized a panel dataset spanning 35 countries and 15 years (2004 to 2018) and employed

panel data estimation techniques for analysis. The results of the study provide strong evidence regarding the relevance of various variables in determining technology-intensive exports. These variables include gross fixed capital formation's impact on total employment, land area per capita, research and development (R&D) expenditures as a percentage of GDP, the proportion of university graduates relative to the population, inward foreign direct investment stock relative to GDP, high-tech manufacturing imports as a share of GDP, country population, the quality of national governance and regulation, and EU membership. These findings carry significant implications for trade and industrial policies within OECD countries, particularly in terms of ensuring the effectiveness of policies aimed at enhancing the technological advancement of exports.

The present study on ICT services export in the CEE region expands upon the existing literature by extending the geographical scope beyond the studies conducted in India. By focusing on the CEE region, this research offers specific insights that contribute to a deeper understanding of the determinants influencing ICT services exports in this context. Furthermore, it enables a comparative analysis between the determinants of high-tech exports in OECD countries and IT software and service exports from India. Such comparative analysis facilitates the identification of commonalities or differences in the determinants across diverse regions, thereby enhancing the comprehensive comprehension of the factors that shape technology-intensive exports. Moreover, this study holds the potential to enrich the policy discourse by identifying region-specific determinants and providing valuable insights into policy measures aimed at fostering the growth of ICT services exports in the CEE region. Policymakers can benefit from these tailored recommendations to enhance the performance and competitiveness of ICT services exports in this region. Furthermore, the empirical findings derived from this study serve to corroborate or complement the results of previous research conducted on high-tech exports in OECD countries and IT software and service exports from India. Consequently, they contribute to strengthening the overall understanding of the determinants governing technology-intensive exports.

CHAPTER 3. METHODOLOGY

This research wants to find out how much government investments in education and R&D help improve ICT service exports in EU countries. The idea is that being part of the EU brings extra benefits like a bigger market, better EU-wide ICT policies, and more funding. These advantages should help increase the good effects of government spending on education and R&D and make the ICT sector grow more in Central and Eastern Europe.

Moreover, the paper aims to investigate the mediating influence of the availability of skilled labor (proxied by enrolled in tertiary education students) and internet infrastructure (indicated by internet availability) on the relationship between FDI and ICT services exports in CEE countries. This hypothesis suggests that the impact of FDI on ICT services exports is channeled through the presence of skilled labor and well-developed internet infrastructure. An increase in FDI inflows can stimulate the demand for skilled labor and enhance internet infrastructure, subsequently leading to a rise in ICT services exports. By analyzing the mediating roles of tertiary students and internet availability, the study seeks to offer a more comprehensive understanding of the pathways through which FDI affects ICT services exports.

The methodology employed in this study encompasses panel data regression analysis to investigate the interrelationships between the endogenous variables, specifically ICT services exports in USD, and various exogenous variables. The exogenous variables considered in the analysis consist of government expenditures on education, foreign direct investment, labor force, exchange rate, R&D expenditures, Internet availability, EU membership, and the number of enrolled in tertiary education students from all programs.

Fixed effects panel data model estimator was employed in the analysis, which accounts for unobserved country-specific characteristics and captures consistent estimates of the relationships between the dependent and independent variables across the CEE countries. This approach allows to control for time-invariant differences between countries and focus on the within-country variation in the data. In order to verify whether fixed

effects estimator is appropriate one, we will also compare it with random effects, and OLS estimators.

Additionally, there were included lagged terms for government expenditures on education, R&D expenditures, enrolled students and FDI in our model to capture potential delayed effects on ICT services exports.

To test the posed hypotheses, we extended the fixed effects regression model by including interaction terms, mediation analysis, lagged variables, and relevant control variables.

For the first hypothesis, we included interaction terms between EU membership and lagged government expenditures on education and R&D expenditures (3.1):

$$\log(\mathrm{XICT})_{it} = \beta_0 + \beta_1 \mathrm{EDEX}_{i,t-1} + \beta_2 \log(\mathrm{FDI})_{i,t-1} + \beta_3 \mathrm{INT}_{it} + \beta_4 \log(\mathrm{LAB})_{it} + \beta_5 \log(\mathrm{EXRT})_{it} + \beta_6 \mathrm{RDEX}_{i,t-1} + \beta_7 \mathrm{RDEX}_{i,t-2} + \beta_8 \log(\mathrm{ENST})_{it} + \beta_9 \log(\mathrm{ENST})_{i,t-1} + \beta_{10} \log(\mathrm{ENST})_{i,t-2} + \beta_{11} \mathrm{EUM}_{it} + \beta_{12}(\mathrm{RDEX}_{i,t-1} * \mathrm{EUM}_{it}) + \beta_{13}(\mathrm{RDEX}_{i,t-2} * \mathrm{EUM}_{it}) + \beta_{14}(\mathrm{EDEX}_{i,t-1} * \mathrm{EUM}_{it}) + \varepsilon, \quad (3.1)$$

where,

"XICT" – denotes the measurement of ICT service exports in current US dollars.

"EDEX" – government expenditure on education, expressed as a percentage of GDP. This category encompasses various types of expenditures, including current, capital, and transfers, with the inclusion of funding from international sources to the government. The term "general government" typically encompasses local, regional, and central governmental entities.

"FDI" – Foreign Direct Investment, which refers to the inflow of net capital into an economy, measured in current US dollars. This category encompasses the movement of equity investments associated with direct investment in the reporting economy, including equity capital, reinvestment of earnings, and other forms of capital. Foreign Direct Investment entails cross-border investments wherein a resident of one economy

gains control or exerts significant influence over the management of an enterprise situated in another economy.

"INT" – representing the percentage of the population aged 25 and above who have utilized the Internet within the previous three months. Internet usage is considered across various devices, including computers, mobile phones, personal digital assistants, game machines, and digital TVs.

"LAB" – referring to the total labor force, which encompasses individuals aged 15 and above who actively contribute their labor to the production of goods and services within a specified time frame.

"EXRT" – the official exchange rate, expressed as the local currency units per US dollar, based on average values for a given period. This rate is determined by national authorities or is derived from the exchange rate prevailing in the legally authorized exchange market. The annual average is calculated using monthly averages.

"RDEX" – representing research and development expenditure as a percentage of GDP. This category encompasses both public and private investments directed towards creative pursuits aimed at advancing knowledge. Research and development activities cover a range of endeavors, including fundamental research, applied research, and experimental development.

"ENST" – representing enrolment in tertiary education, all programs, both sexes in absolute number.

"EUM" – assumed as a binary indicator, taking a value of 1 if the country is a member of the European Union and a value of 0 if it is not.

Here, β_{12}, β_{13} and β_{14} represent the additional effects of lagged government expenditures on education and R&D expenditures on ICT services exports for EU member countries. These interaction terms expected to be statistically significant and positive if the effect on ICT services exports is stronger for EU member countries in the CEE region.

For the second hypothesis, a mediation analysis was performed to estimate the indirect effects of lagged FDI on ICT services exports through skilled labor and internet availability.

Regressions purposed for estimation the effects of lagged FDI on the mediator variables: skilled labor (3.2) and internet availability (3.3):

$$\log(\mathrm{ENST})_{it} = \beta_0 + \beta_1 \mathrm{EDEX}_{i,t-1} + \beta_2 \log(\mathrm{FDI})_{i,t-1} + \beta_3 \mathrm{INT}_{it} + \beta_4 \log(\mathrm{LAB})_{it} + \beta_5 \log(\mathrm{EXRT})_{it} + \beta_6 \mathrm{RDEX}_{i,t-1} + \beta_7 \mathrm{RDEX}_{i,t-2} + \beta_8 \log(\mathrm{ENST})_{i,t-1} + \beta_9 \log(\mathrm{ENST})_{i,t-2} + \beta_{10} \mathrm{EUM}_{it} + \beta_{11}(\mathrm{RDEX}_{i,t-1} * \mathrm{EUM}_{it}) + \beta_{12}(\mathrm{RDEX}_{i,t-2} * \mathrm{EUM}_{it}) + \beta_{13}(\mathrm{EDEX}_{i,t-1} * \mathrm{EUM}_{it}) + \varepsilon \quad (3.2)$$

$$\mathrm{INT}_{it} = \beta_0 + \beta_1 \mathrm{EDEX}_{i,t-1} + \beta_2 \log(\mathrm{FDI})_{i,t-1} + \beta_3 \log(\mathrm{LAB})_{it} + \beta_4 \log(\mathrm{EXRT})_{it} + \beta_5 \mathrm{RDEX}_{i,t-1} + \beta_6 \mathrm{RDEX}_{i,t-2} + \beta_7 \log(\mathrm{ENST})_{it} + \beta_8 \log(\mathrm{ENST})_{i,t-1} + \beta_9 \log(\mathrm{ENST})_{i,t-2} + \beta_{10} \mathrm{EUM}_{it} + \beta_{11}(\mathrm{RDEX}_{i,t-1} * \mathrm{EUM}_{it}) + \beta_{12}(\mathrm{RDEX}_{i,t-2} * \mathrm{EUM}_{it}) + \beta_{13}(\mathrm{EDEX}_{i,t-1} * \mathrm{EUM}_{it}) + \varepsilon \quad (3.3)$$

The fixed effects panel data model estimator with interaction terms, mediation analysis, and lagged variables was selected as the methodology for testing the hypotheses because it offers several advantages.

Firstly, CEE countries have unique factors affecting ICT services exports that are time-invariant. Thus, unobserved country-specific characteristics can be captured, and each country will be allowed to have its own intercept term in the model.

Interaction terms are also included in the methodology to examine how the effects of lagged government expenditures on education and R&D expenditures are moderated by EU membership. This provides a nuanced understanding of these variables' impact on ICT services exports in the CEE region.

Additionally, the use of mediation analysis helps us estimate the indirect effects of lagged FDI on ICT services exports through the mediating variables of skilled labor and internet availability. This allows us to shed light on the underlying mechanisms driving the relationship between FDI and ICT services exports.

Finally, including lags for government expenditures on education, R&D expenditures, tertiary students, and FDI to capture potential delayed effects on ICT services exports enables us to better account for the dynamic relationships between these variables over time.

In conclusion, chosen methodology, allows to provide robust evidence and comprehensive insights into the determinants of ICT services exports in CEE countries, specifically regarding the posed hypotheses. By addressing potential biases and limitations, this approach ensures a reliable investigation of the research questions at hand.

CHAPTER 4. DATA

4.1. Data issues resolving

The study utilized data sourced from the World Bank, UNESCO Institute for Statistics, and Eurostat databases. The panel dataset comprised information from 14 CEE countries, including Ukraine, Poland, Moldova, Slovenia, Slovak Republic, Hungary, Georgia, Armenia, Czechia, Bulgaria, Lithuania, Latvia, Croatia, and Azerbaijan. The dataset encompassed a time span of 20 years, ranging from 2002 to 2021. Also, we downloaded data for 2000-2001 to include two lagged periods for 2002 year.

However, it is essential to acknowledge that not all countries and years possessed complete data for all variables, resulting in an unbalanced panel dataset. To fix data issues, we applied three different techniques concerning in which place data was missed: at the beginning of the observation period (starting from the 2000 year), in the middle of the observed period (starting not earlier than 2001 and ending not later than 2020), at the end of the period (ending with 2021).

For the first scenario we have missed values for the next series: RDEX (Moldova: 2000-2002;) EDEX (Slovenia: 2000, Bulgaria: 2000, Lithuania: 2000, Croatia: 2000-2001), XICT (Latvia: 2000-2007), ENST (Azerbaijan: 2000-2005). To fill missed values, we applied CAGR formula for the five following periods and based on the CAGR value, we will fill previous year value.

Second case has missed values for the following data: XICT (Slovakia: 2004-2007), RDEX (Georgia: 2006-2012), EDEX (Latvia: 2005, Croatia: 2005-2006), INT (Azerbaijan: 2003-2004). For such cases we will take values for years before and after gap, find arithmetic difference and will apply linear formula for each missed year.

Third case should properly handle next data: EDEX (Ukraine: 2021, Poland: 2021, Moldova: 2021, Slovenia: 2021, Slovakia: 2021, Hungary: 2021, Czechia: 2021, Bulgaria: 2021, Lithuania: 2020-2021, Latvia: 2021, Croatia: 2021, Azerbaijan: 2021), ENST (Bulgaria: 2021, Croatia: 2021, Czechia: 2021, Hungary: 2021, Latvia: 2021, Lithuania: 2021, Poland: 2021, Romania: 2021, Slovakia: 2021, Slovenia: 2021). For this scenario, we will

apply similar technique as for the first case. The only difference is that the value of the next year will be based on five previous years.

After data issues were fixed, we have the complete dataset with 308 records for panel data. In the Table 1 there is an example of the data row from obtained dataset for 2020 year in Ukraine.

Table 1. Record example

Column name, measure	Value
ICT service export, USD, bln	5.181
EDEX, %	5.38
FDI, USD, mln	304
INT, %	75.04
LAB, mln	20.6
EXRT	26.96
RDEX, %	0.4
EUM	0
ENST, mln	1.5

4.2. Descriptive statistics

Descriptive statistics of the gathered and clean data, which contains minimum, maximum, mean, median, standard deviation values for each numeric column presented below in the Table 2.

We observe a considerable range in ICT service exports, with values as low as 3.6 million USD and as high as 11.58 billion USD. The average export value is 902.5 million USD, but the lower median of 298.9 million USD suggests a skewed distribution.

Government expenditure on education varies from 1.91% to 9.51% of GDP in the region, with an average and median close together at around 4.46% and 4.49%, respectively. The wide-ranging values of FDI in the dataset go from about -64.4 billion USD up to around 167.6 billion USD. This significant variation results in an average FDI of 4.7 billion

USD, while the median is much lower at 1.53 billion USD, indicating possible outliers in the data.

Table 2. Variables descriptive statistics

Variable	Min.	Max.	Mean	Median	St. dev.
XICT	3598000	11580000000	902484299	298885000	1525774280
EDEX	1.906	9.510	4.462	4.490	1.23
FDI	-64364899191	167560108497	4720951995	1526833748	14376795100
INT	0.1478	91.1796	48.3175	54.1050	27.39
LAB	853714	23195753	5001374	2325555	6317601
EXRT	0.4808	578.7630	60.6759	3.9213	130.75
RDEX	0.08367	2.60393	0.77192	0.67839	0.52
ENST	75939	2847713	443442	167443	662296
EUM	Categorical variable: 0/1				

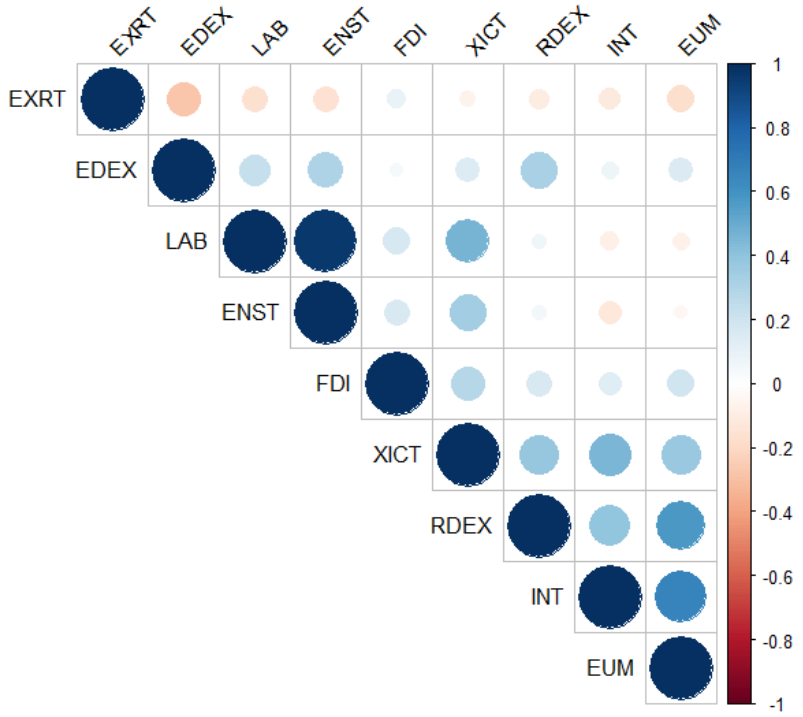
In terms of internet usage for individuals aged 25 and above, the percentage ranges from 0.1478% to 91.1796%. The dataset displays an average internet usage of 48.32% and a higher median of 54.11%, hinting at a left-skewed distribution. When it comes to the total labor force, we see figures varying from 853,714 to 23,195,753, with an average of approximately 5 million and a median of around 2.33 million.

The official exchange rate showcases an interesting range, with values from 0.4808 to 578.7630. The average exchange rate is 60.68, and the median is quite low at 3.92, suggesting differing economic situations across the countries analyzed. Research and development expenditure exhibits some variation as well, covering a span from 0.08367% to 2.60393% of GDP. These values result in an average expenditure of 0.77% and a median of 0.68%.

Lastly, enrollment in tertiary education displays a minimum of 75,939 students and a maximum of 2,847,713. The average enrollment in the dataset is 443,442, while the median is much lower at 167,443, possibly reflecting disparities in the education sectors of different countries.

As a next step, we conducted correlation analysis to determine possible multicollinearity between variables within a dataset (Fig. 5).

Figure 5. Correlation matrix visualization



We observe that ICT services exports show positive correlations with education expenditure, FDI, Internet usage, labor force, R&D expenditure, EU membership, and enrollment in tertiary education. This suggests a possible association between increasing these factors and higher ICT services exports. The strongest positive correlations are with Internet usage and labor force, implying that a higher percentage of Internet users and a larger labor force might contribute significantly to the growth of the ICT sector.

We found that moderately strong positive correlation exists between EU membership and Internet usage, as well as R&D expenditures. The reason could be due to the EU's policies, available financial resources, and collaborative initiatives.

The labor force and enrollment in tertiary education also have a high positive correlation. This suggests that countries with larger labor forces also have a higher number of students enrolled in tertiary education, which may impact the ICT industry in terms of workforce skill level and availability.

Exchange rate has relatively weak correlations with other variables, but notably, it shows a negative correlation with education expenditure, Internet usage, and EU membership. This indicates that countries with higher exchange rates might have somewhat lower education expenditure and Internet usage levels and are less likely to be in the EU.

To assess the presence of multicollinearity in the given correlation matrix, we should look for high correlation values among the independent variables (predictor variables). Based on the provided matrix, we observe some evidence of multicollinearity among a few independent variables.

A strong positive correlation between the labor force and enrollment in tertiary education: this suggests that these two variables might be moving together, making it challenging to isolate their individual effects on the dependent variable (ICT services exports). We consider this result and will remove LAB (labor force) from the regression model.

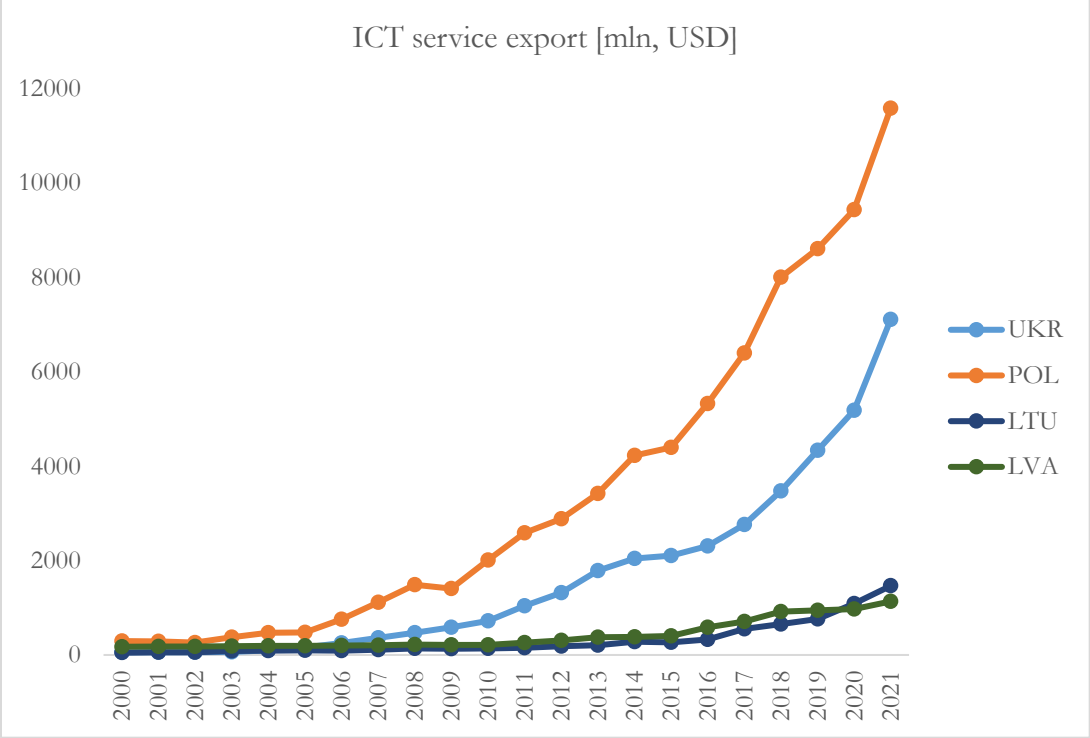
A moderately strong positive correlation between EU membership and Internet usage as well as R&D expenditure: this indicates that EU membership is associated with higher levels of Internet usage and R&D spending, which could cloud the separate effects of these variables on the dependent variable. For this case we will keep all variables in resulting regression model.

4.3. Data distribution

In Figures 6-8, we study the trends of ICT service exports for CEE countries grouped by geographical principle. Built line graphs represent the changes in ICT services export volumes over a 22-year period, with the horizontal x-axis indicating the years and the y-axis showing the value of ICT services export measured in millions of USD.

The first graph reveals that Poland experienced the most significant growth in ICT services export, with a value of 11,580 million USD in 2021, compared to 295 million USD in 2000. Notably, Polish ICT exports accelerated after its EU accession in 2004, with substantial growth between 2009 and 2011. Ukraine, initially starting with an export value similar to Poland (56 million USD in 2000), also saw considerable growth in ICT services export, reaching 7,107 million USD in 2021. Significantly, the graph displays steady growth for Ukraine, with a sharp increase between 2019 and 2021.

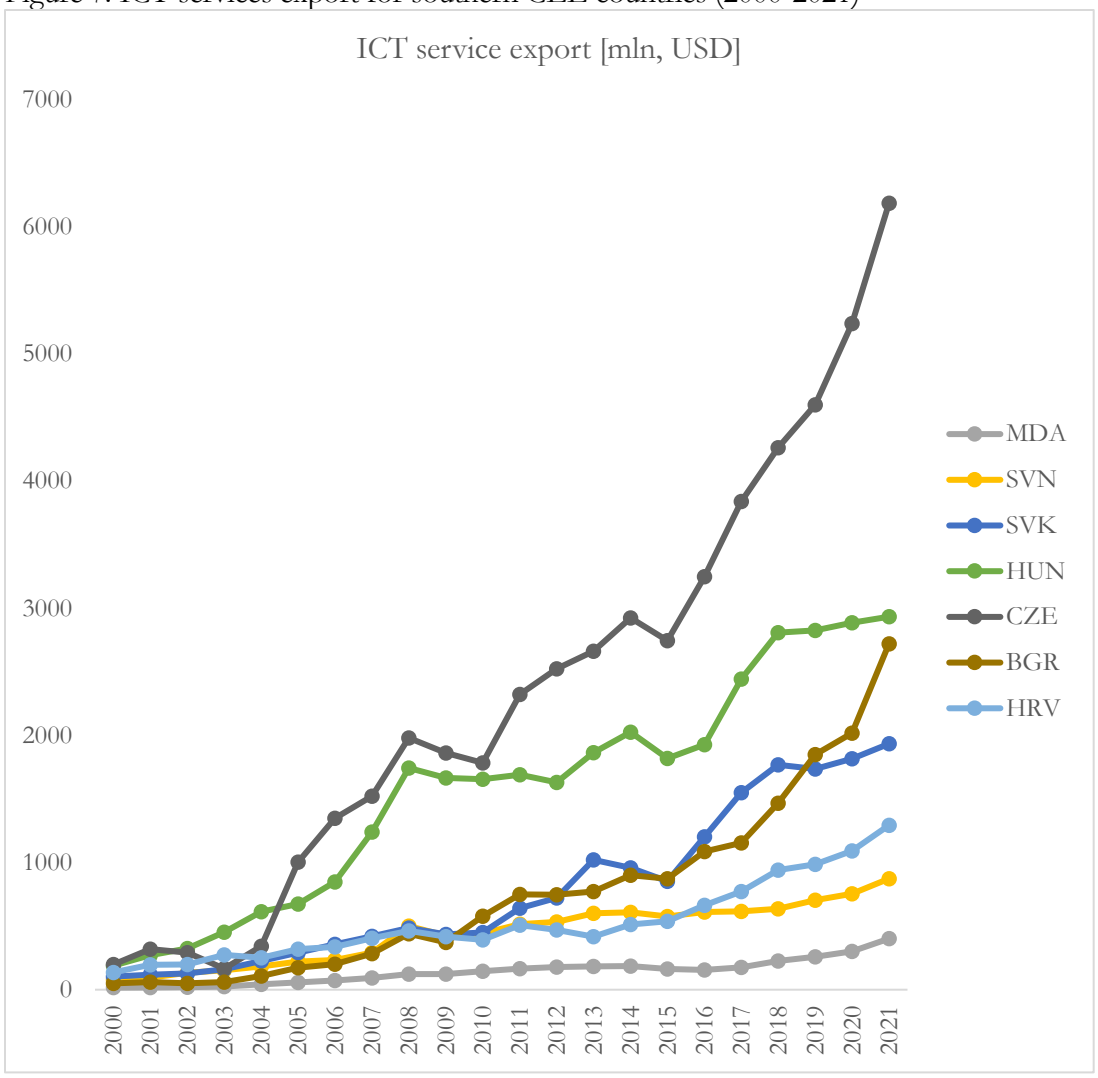
Figure 6. ICT services export for nothern CEE countries (2000-2021)



Source: World Bank data

Slovakia, Hungary, and the Czech Republic also shown considerable growth in ICT services export over the examined years. Slovakia grew from 103 million USD in 2000 to 1,933 million USD in 2021, while Hungary saw an increase from 189 million USD in 2000 to 2,932 million USD in 2021. The Czech Republic's ICT services export had a value of 197 million USD in 2000, which expanded to 6,183 million USD in 2021. These three countries present relatively similar growth trajectories, with some fluctuations in certain years.

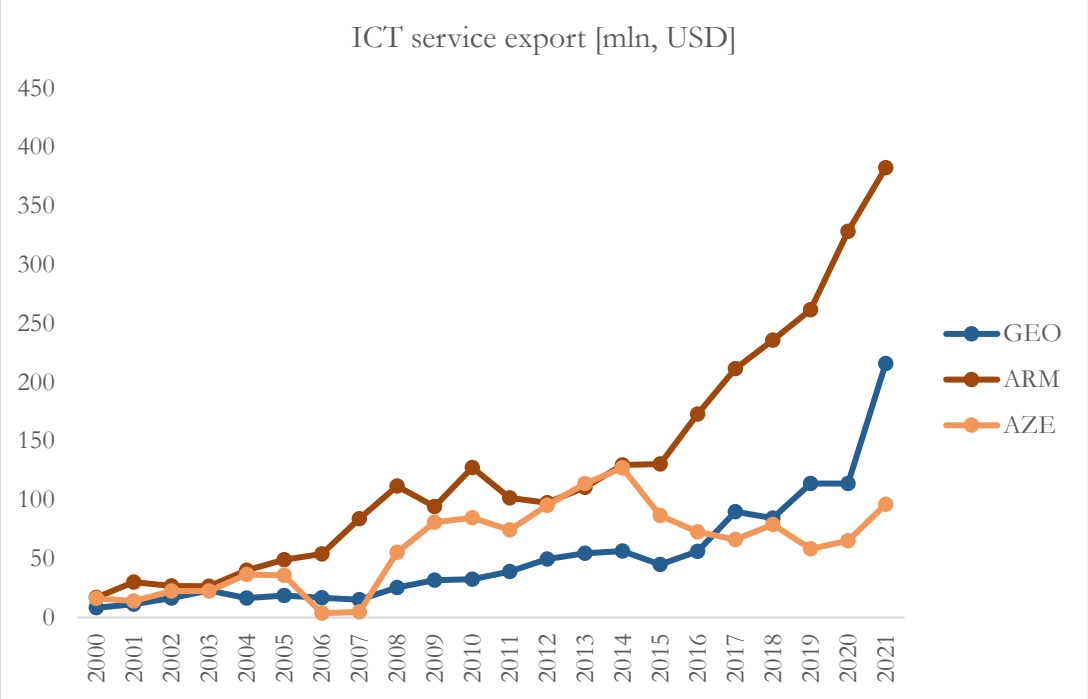
Figure 7. ICT services export for southern CEE countries (2000-2021)



Source: World Bank data

Georgia, Armenia, and Azerbaijan reported their ICT services exports grow more modestly over the 21-year period. Georgia's export volume went from 8 million USD in 2000 up to 216 million USD in 2021, while Armenia and Azerbaijan registered export values of 382 million USD and 96 million USD in 2021, up from 17 million USD and 16 million USD in 2000, respectively. These countries have seen more fluctuation in yearly ICT services export but show overall growth.

Figure 8. ICT services export for eastern CEE countries (2000-2021)



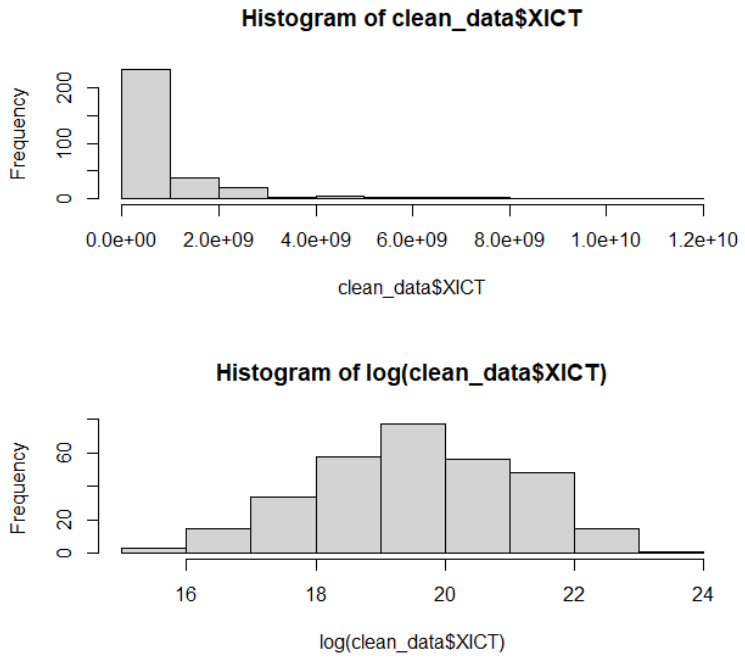
Source: World Bank data

To better understand the distribution of ICT services exports variable and how to better process and interpret it, on the Figure 9 we have developed a histograms based on the raw data obtained and log-transformed data. This transformation can often reveal patterns that might not be easily discernible in the raw data.

Analyzing the histogram, the distribution of ICT services export values is positively skewed, with a higher concentration of countries falling within the lower-end intervals. It indicates that most of the countries in the analysis have relatively smaller ICT services

exports. The histogram shows a positive skew, with a few outlier countries like Poland and Ukraine having high export values. It is clearly visible that the log-transformed distribution of values appears more symmetric and closer to a normal distribution compared to the histogram of raw data. This observation suggests that the variability of ICT services exports across countries might be more similar when considering relative differences in export values, rather than absolute differences. It also indicates that the large differences in export values between countries, especially when comparing major exporters like Poland and smaller ones such as Georgia, might be due to exponential growth rather than a linear pattern. So that, we will choose log-transformed data of the ICT services export variable for our analysis.

Figure 9. Histograms of the export of ICT services variable



Source: World Bank data

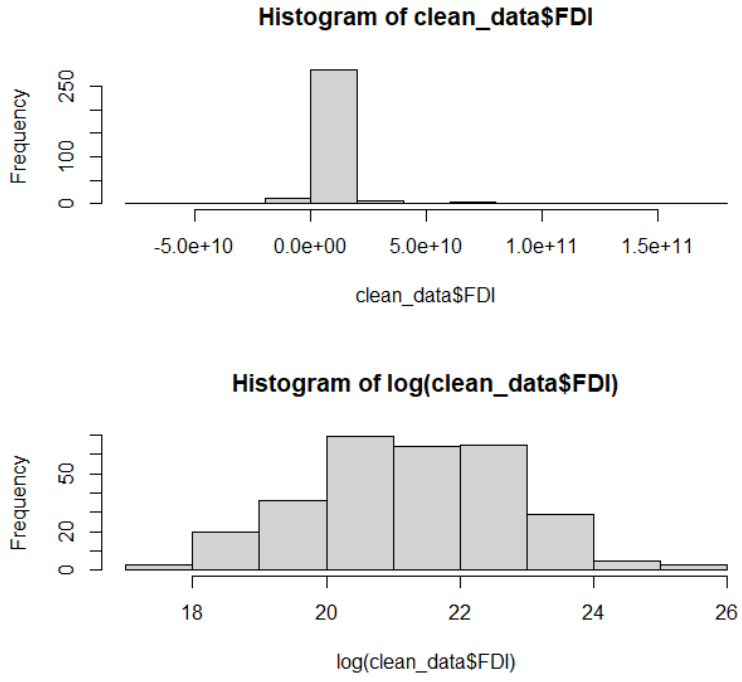
The FDI inflows for analyzed countries are highly volatile and prone to significant fluctuations. This could be a result of various external factors such as macroeconomic conditions, political stability, and global investment climate. Certain countries, such as

Hungary and Poland, have consistently high FDI inflows. While others, like Moldova and Georgia, have relatively lower FDI inflows. For instance, FDI inflows in Ukraine turned negative in 2015 but rose back in subsequent years.

On the Figure 10, the histogram of FDI inflows exhibits a right-skewed distribution. This indicates that, most of the countries have relatively lower FDI inflows, with few countries receiving significantly higher amounts of foreign investment. The log-transformed histogram tends to show a more normal distribution compared to the regular distribution. That's why, taking the logarithm of FDI values may provide a better understanding of the patterns and reduce the impact of extreme values.

Certain years, such as 2007-2008 and 2020-2021, show relatively higher FDI inflows as compared to other periods in the dataset. This could be attributed to specific global economic events (e.g., pre-global financial crisis booms and post-COVID recovery) influencing worldwide FDI trends.

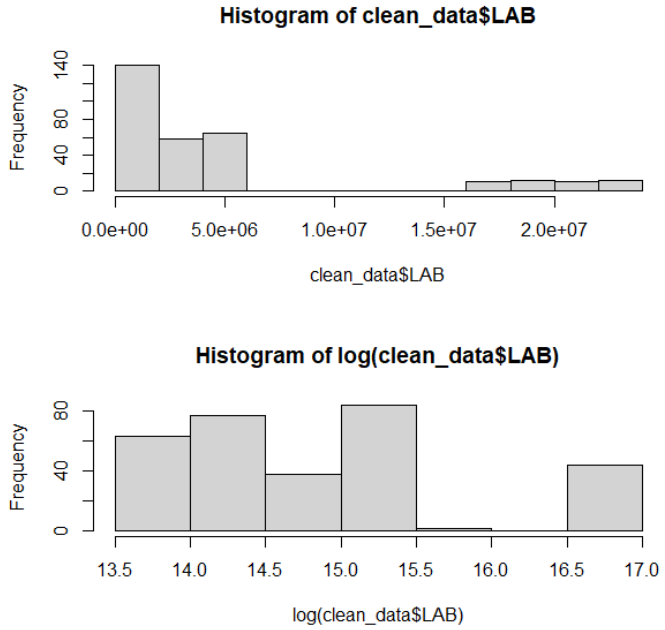
Figure 10. Histograms of the FDI variable



Source: World Bank data

From the analysis of the labor force visual representation (Fig. 11), there is considerable variation in the size of the labor force across the countries. The labor force has been decreasing in some countries over the analyzed years. Ukraine, Moldova, and Latvia exhibit a downward trend in the total labor force. This could be attributed to factors such as aging populations, migration, and shrinking working-age populations. Some countries, such as Azerbaijan and Hungary, have experienced an increase in their labor force over the years. The reasons could be the following: population growth, higher labor force participation rates, or economic development attracting more workers into the labor force. The variable histogram may be right-skewed, with a smaller number of countries having larger labor forces than the majority. The log-transformed histogram tends to follow a more normal distribution, suggesting that transforming the raw labor force data using logarithmic values may provide a better understanding of the global labor force distribution and the relativeness of country sizes in terms of their labor force. The labor force changes over time are not uniform across countries.

Figure 11. Histograms of the LAB variable

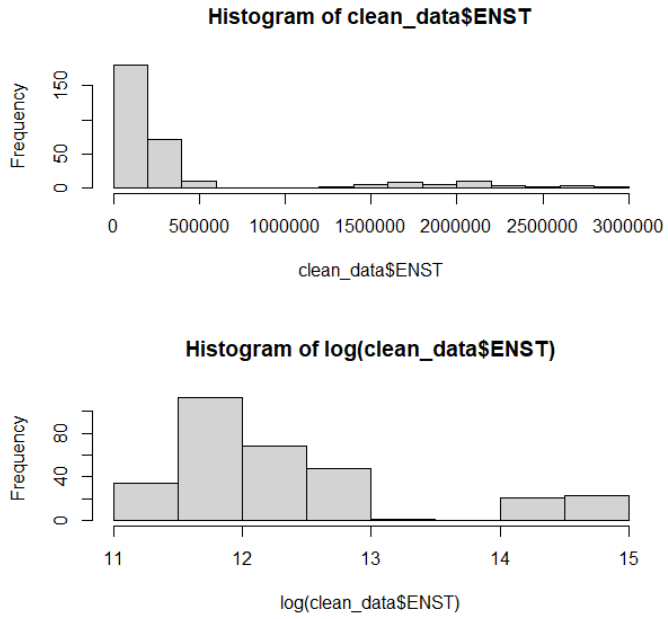


Source: World Bank data

Upon examining enrolled tertiary students, overall, there is an upward trend in the enrolment of students in tertiary education programs for most of the countries during the early 2000s. Factors such as economic growth and expanded access to higher education might have contributed to this increase. Some countries experienced a declining trend in tertiary enrollment in the latter years, such as Ukraine and Latvia. This decrease may be due to demographic changes, the restructuring of the higher education system, or decreased investments in education.

The histogram of the tertiary enrolled students (Fig. 12) variable appears to be right-skewed, with a smaller number of countries having larger enrolment numbers. The log-transformed histogram tends to follow a more normal distribution.

Figure 12. Histograms of the ENST variable

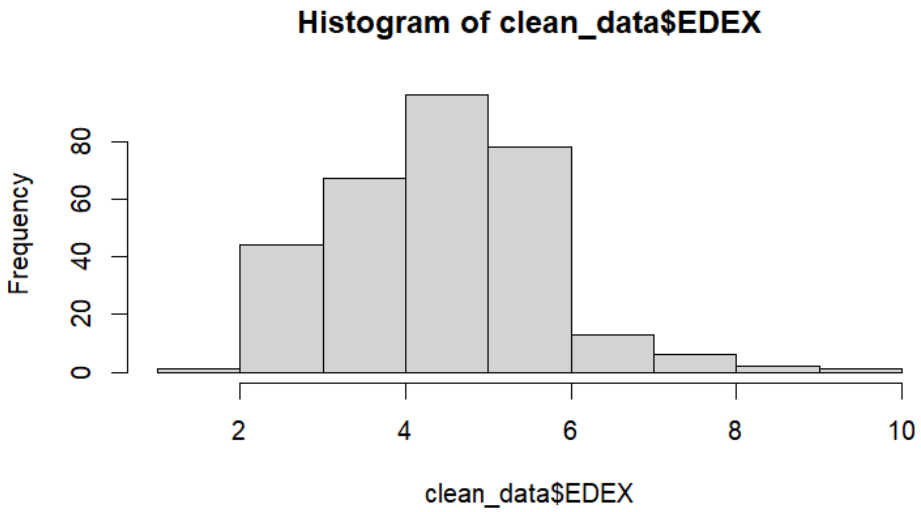


Source: World Bank data

Government expenditures on education as a percentage of GDP vary significantly across countries. In some countries like Lithuania and Latvia, EDEX percentages are generally higher compared to countries like Slovenia, Azerbaijan, and Georgia, which

exhibit comparatively lower rates. Over time, EDEX percentages demonstrate fluctuations in different countries. Some countries like Moldova, Ukraine, and Slovenia have registered an upward trend in EDEX, which might be attributed to increased investments in education or reforms in the education system. In contrast, EDEX levels have either decreased or presented fluctuations in countries like Armenia, Latvia, and Bulgaria. The histogram distribution of the EDEX data (Fig. 13) may exhibit a normal or slightly skewed distribution, with most countries showing EDEX percentages in the middle range.

Figure 13. Histogram of the EDEX variable

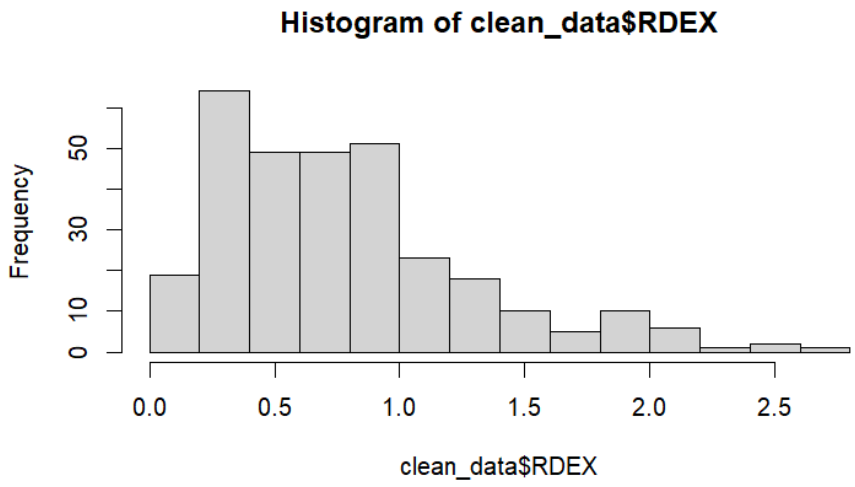


Source: World Bank data

R&D expenditure as a percentage of GDP also varies considerably across countries. Countries like Slovenia, Czech Republic, and Croatia show higher percentages of R&D expenditure comparing to countries like Moldova, Georgia, and Armenia. Across years, R&D expenditure percentages also exhibit fluctuations for different countries. Some countries, like Poland, Hungary, and Latvia, show a general upward trend in R&D expenditure over the years, potentially reflecting increased government focus and investment on research and innovation. In contrast, countries like Ukraine, Azerbaijan, and Armenia have either stagnated or demonstrated decreasing trends in R&D expenditure.

The histogram distribution (Fig. 14) of R&D expenditure data may present a slightly skewed distribution towards countries with lower R&D expenditure percentages.

Figure 14. Histogram of the RDEX variable

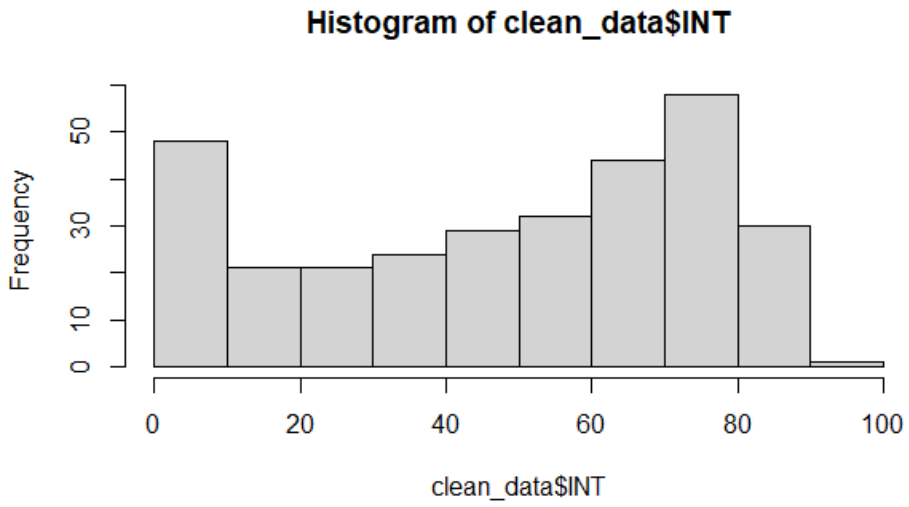


Source: World Bank data

Internet usage has shown a significant increase over the years in all countries. There is a clear positive trend for countries like Ukraine (from 0.72% in 2000 to 79.22% in 2021) and Moldova (from 1.28% in 2000 to 61.29% in 2021), showcasing an increasing percentage of the population aged 25 and above utilizing the internet. A few countries started with higher initial internet usage rates, such as Slovenia (15.11% in 2000) and Slovakia (9.43% in 2000). These countries have also seen substantial growth over the years, with almost universal adoption by 2021 (Slovenia: 89.00%; Slovakia: 88.93%). Countries with lower initial internet usage rates, like Azerbaijan and Georgia, have shown remarkable progress. Azerbaijan's internet usage increased from 0.15% in 2000 to 86% in 2021, while Georgia's increased from 0.48% in 2000 to 76.44% in 2021. This suggests that these countries have made significant strides towards digital inclusion over the years. The histogram distribution (Fig. 15) for INT data would likely show a right-skewed distribution in the early 2000s, representing a higher concentration of countries with lower internet

usage rates. As years progress, the distribution should become more symmetric, reflecting a more even spread between low and high internet usage rates. The expansion of internet usage across different countries may be attributed to several factors, such as improvements in technology and infrastructure, digital awareness, increased availability, and affordability of devices, and national or regional government policies promoting digitalization. In conclusion, the INT data suggests that internet usage has grown consistently across the various countries reported. This increase in internet usage reflects advancements in technology, digital awareness, and government policies supporting digital inclusion.

Figure 15. Histogram of the INT variable

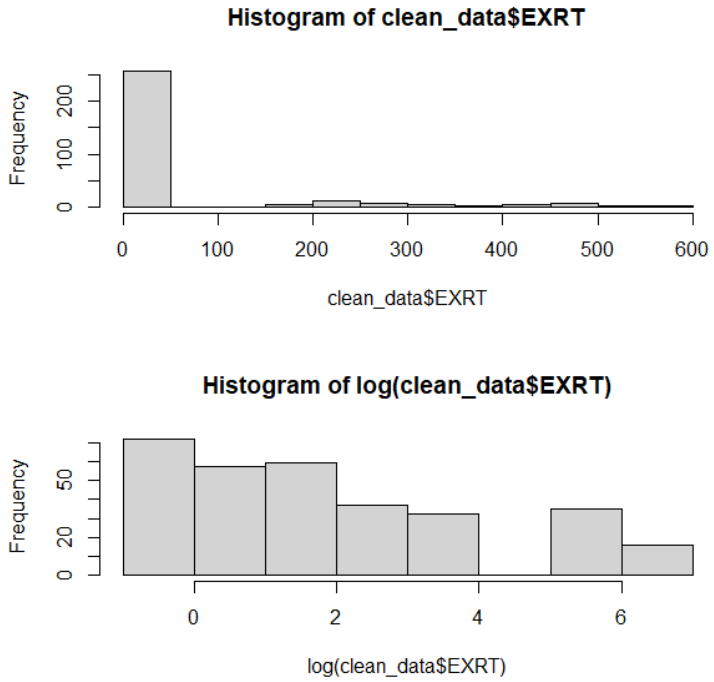


Source: World Bank data

The histogram for exchange rate (Fig. 16) displays a highly right-skewed distribution. This indicates that most countries have a low exchange rate with the US dollar, while a few have significantly higher exchange rates. The histogram for log-transformed data would be more symmetrical and less skewed. Countries that have experienced substantial depreciation in their currencies against the US dollar, such as Ukraine, Moldova, and Armenia, would have a more notable presence in the right tail of the EXRT histogram. However, their impact would be less pronounced in the log histogram, as the

transformation helps normalize their values. For countries that have joined the Eurozone, such as Slovenia, Slovakia, and Lithuania, the histograms for both variables would show a convergence to a relatively stable exchange rate with the US dollar after adopting the Euro in the late 2000s. This is a clear indication of the benefits of currency integration in reducing exchange rate risks and uncertainties.

Figure 16. Histograms of the EXRT variable



Source: World Bank data

Analyzing the log histogram would likely reveal more insights and trends compared to the exchange rate variable histogram, as the log transformation helps reduce the impact of extreme values and reveals more subtle changes in exchange rate patterns over time.

CHAPTER 5. RESULTS

5.1. Model verification

Before reporting quantitative analysis results, a comprehensive analysis of the fixed effects, random effects, and OLS models was conducted for the first regression to determine the most appropriate model for our data.

For the fixed effects model (Table 3), the Total Sum of Squares was 218.11 and the Residual Sum of Squares was 40.841, resulting in an R-squared of 0.81275 and an adjusted R-squared of 0.79432. The F-statistic was 91.871 with 12 and 254 degrees of freedom (DF), and the p-value was smaller than $2.22e^{-16}$, indicating the model's overall significance.

Table 3. Fixed effects model significance test results

Result name	Value
Total Sum of Squares	218.11
Residual Sum of Squares	40.841
R-Squared	0.81275
Adj. R-Squared	0.79432
F-statistic	91.871 on 12 and 254 DF
p-value	$< 2.22e^{-16}$

The random effects model (Table 4) yielded a Total Sum of Squares of 238.92 and a Residual Sum of Squares of 54.968. The R-squared and adjusted R-squared were 0.76994 and 0.7596, respectively. The Chi-squared statistic was 893.543 with 12 DF, and the p-value was also less than $2.22e^{-16}$.

The OLS model (Table 5) showed a residual standard error of 0.5903 with 267 degrees of freedom. The multiple R-squared and adjusted R-squared values were 0.8534 and 0.8468, respectively. The F-statistic was 129.6 with 12 and 267 DF, and the p-value was smaller than $2.2e^{-16}$.

Table 4. Random effects model significance test results

Result name	Value
Total Sum of Squares	238.92
Residual Sum of Squares	54.968
R-Squared	0.76994
Adj. R-Squared	0.7596
Chisq	893.543 on 12 DF
p-value	$< 2.22e^{-16}$

Table 5. OLS model significance test results

Result name	Value
Residual standard error	0.5903 on 267 degrees of freedom
Multiple R-squared	0.8534
Adjusted R-squared	0.8468
F-statistic	129.6 on 12 and 267 DF
p-value	$< 2.2e^{-16}$

To compare the fixed and random effects models, we performed the Hausman test (Table 6), which resulted in a chi-squared statistic of 90.852, 12 DF, and a p-value of $3.377e^{-14}$. This outcome supports the alternative hypothesis that random effects model is inconsistent.

Finally, we conducted the pFtest (Table 7) test of individual and/or time effects based on the comparison of the within and the pooling model, between the fixed effects model and the OLS model. The test produced an F-statistic of 24.975 with 13 and 254 DF and a p-value smaller than $2.2e^{-16}$. This result indicates significant effects and implies that the fixed effects model is more suitable for our data.

Table 6. Hausman test results

Result name	Value
chisq	90.852
df	12
p-value	$3.377e^{-14}$

Table 7. Test of individual and/or time effects results

Result name	Value
F	24.975
df1	13
df2	254
p-value	$< 2.2e^{-16}$

In conclusion, based on the results of these tests, we determined that the fixed effects model is the most appropriate choice for analyzing the data in our study. This model best accounts for the factors influencing ICT service exports in the CEE region and provides the most reliable and robust insights into our research questions.

5.2. Quantitative analysis

After running regression analysis to test first hypothesis, we performed tests for heteroscedasticity and serial correlation.

Based on the results of the Breusch-Pagan test (BP = 34.211, df = 13, p-value = 0.001118), we have evidence to suggest that heteroscedasticity is present in the model's error terms.

In response to the detected heteroscedasticity, we computed robust standard errors using the Arellano method and we obtained coefficient estimates and standard errors that are robust to heteroscedasticity. Then we compared the results of the standard errors with the Arellano robust standard errors. The comparison indicated that the standard errors

have changed under the Arellano method, leading to differences in significance levels for some variables.

In summary, after accounting for heteroscedasticity with the Arellano robust standard errors, some variables changed their significance levels - specifically, lag_log_FDI, lag1_log_ENST, and lag1_RDEX:EUM became more significant. For example, lag_log_FDI becomes significant at the 5% level when using Arellano robust standard errors, which was not the case in the standard results.

Also, based on the results of the Durbin-Watson test (DW = 0.7775, p-value < $2.2e^{-16}$), there is evidence that serial correlation is present in the model's error terms.

In response to the detected serial correlation, standard errors were computed using the Driscoll-Kraay Robust Covariance Matrix Estimator, obtaining coefficient estimates and standard errors that are robust to both heteroscedasticity and serial correlation.

Then, we compared the results of the standard errors with the Driscoll-Kraay robust standard errors. The comparison indicated that the standard errors have changed under the Driscoll-Kraay method, leading to differences in significance levels for some variables. For example, lag_log_FDI becomes significant at the 5% level when using Driscoll-Kraay robust standard errors, which was not the case in the standard results.

In conclusion, after accounting for serial correlation with the Driscoll-Kraay robust standard errors, some variables changed their significance levels - specifically, lag_log_FDI and lag1_RDEX:EUM became more significant.

Based on the test results and estimates model could be improved with additional control variables or including more countries, for which data was not available during the research. But still, we have some insights from the performed model.

In result, our regression analysis presented in Table 8 investigates the relationship between government investments in education and R&D, along with several other economic factors, and ICT services exports (log(XICT)) in the CEE region. The key findings and interpretations are as follows:

1. Government expenditure on education (lag_EDEX) has a positive and significant impact on ICT services exports (log(XICT)) for non-EU countries. However, when considering the interaction term with the EU membership variable, the net effect for EU members is negative. This suggests a different dynamic for EU countries when it comes to the relationship between education investment and ICT service exports, potentially due to varying regulations, policies, and market forces within the European Union.
2. Foreign Direct Investment (lag_log_FDI) demonstrates a positive but statistically insignificant association with ICT services exports (log(XICT)). This implies that there might be other factors affecting the relationship between FDI and ICT service exports, and the direct impact of FDI cannot be reliably measured within this model.
3. Internet usage (INT) exhibits a positive and highly significant impact on ICT services exports (log(XICT)). This underlines the importance of widespread internet usage, indicating that greater engagement with digital technologies contributes to growth in the ICT service exports.
4. Official exchange rate (log(EXRT)) shows a negative but statistically insignificant relationship with ICT service exports (log(XICT)), suggesting that the exchange rate might not be a reliable determinant factor affecting ICT service exports in the studied countries.
5. Research and development expenditure, one- and two-year lags (lag1_RDEX and lag2_RDEX), display complex and time-sensitive relationships with ICT service exports (log(XICT)) and EU membership. The effect of R&D expenditure on ICT exports varies depending on the time lag and the country's EU membership status, highlighting the nuanced nature of innovation's contribution to the sector.
6. Enrollment in tertiary education (log(ENST), lag1_log_ENST, and lag2_log_ENST) has a significant immediate negative effect on ICT services exports (log(XICT)). However, the impact of enrollment with one- and two-year

lags lacks statistical significance, indicating the importance of considering short-term dynamics in human capital development.

7. EU membership (EUM) demonstrates a positive and highly significant impact on ICT services exports (log(XICT)), emphasizing the advantages of regional integration in promoting growth in the ICT sector and fostering a favorable environment for increased exports.

Considering these results, we find evidence supporting the first hypothesis to some extent. The impact of government spending on education and research and development (R&D) on ICT services exports is affected by EU membership, but the relationship is found to be more complex than initially hypothesized.

The EU membership does amplify the positive impact of R&D expenditure on ICT service exports when considering a one-year lag but reduces the impact of education spending. This suggests that an interplay between different factors, like diminishing returns on specific resources and lag times, should be considered when considering the impact of these variables in the context of EU membership.

In summary, the results reveal that increased government expenditure on education, higher internet usage, EU membership, and enrollment in tertiary education (with a one-year lag) positively influence the logged ICT service exports. The effects of FDI and the official exchange rate on ICT service exports are statistically insignificant, and the impact of R&D expenditures is complex and time sensitive.

To access second hypothesis two additional regressions were examined with the results:

1. The direct effect of FDI (lag_log_FDI) on log(XICT) is positive but not statistically significant, with a coefficient of 0.011 and a standard error of 0.017. It implies that there is no strong evidence of a direct impact of FDI on ICT services exports when considering the mediation of enrolled students and internet availability.
2. The effect of enrolled students (log(ENST)) on log(XICT) is negative and significant, with a coefficient of -1.749 and a standard error of 0.569. This result is statistically significant at the 1% level. It suggests that an increase in enrolled

students may have a negative impact on ICT services exports when not accounting for other factors.

3. The effect of 1-period lagged enrolled students (lag1_log_ENST) on log(XICT) is positive but not statistically significant, with a coefficient of 0.95 and a standard error of 0.914.
4. The effect of 2-period lagged enrolled students (lag2_log_ENST) on log(XICT) is negative but not statistically significant, with a coefficient of -0.224 and a standard error of 0.563.
5. The effect of FDI (lag_log_FDI) on enrolled students is negative but not statistically significant, with a coefficient of -0.0003 and a standard error of 0.002. Given the provided result, there is no significant support for the claim that FDI directly impacts the availability of skilled labor (enrolled students).
6. The effect of FDI (lag_log_FDI) on internet availability is positive but not statistically significant, with a coefficient of 0.043 and a standard error of 0.666.

Although, Breusch-Pagan and Durbin-Watson tests bring evidence of the heteroscedasticity and serial correlation presented in the mediation regressions, our key variables were not affected. Since, robust standard errors show same results for variables of the interest.

In summary, based on these results, the evidence does not strongly support the second hypothesis, which claims that the availability of skilled labor (enrolled students) and internet infrastructure mediates the relationship between FDI and ICT services exports in the CEE region. The results suggest that neither the FDI relationship with enrolled students nor its relationship with internet availability is statistically significant. While there is a negative and significant relationship between enrolled students and ICT services exports, a clear mediation effect is not observable in this analysis.

Table 8. Regression results

	Dependent variable					
	log(XICT)		log(ENST)		INT	
Independent variable	estimate	std. error	estimate	std. error	estimate	std. error
lag_EDEX	0.362***	(0.055)	0.006	(0.006)	5.798***	(2.176)
lag_log_FDI	0.011	(0.017)	-0.0003	(0.002)	0.043	(0.666)
INT	0.028***	(0.002)	-0.001***	(0.0002)		
log(EXRT)	-0.011	(0.033)	0.003	(0.004)	2.665**	(1.324)
lag1_RDEX	-0.914	(0.671)	0.215**	(0.073)	10.999	(26.837)
lag2_RDEX	0.558	(0.691)	-0.24***	(0.075)	-37.169	(27.572)
log(ENST)	-1.749**	(0.569)			-79.737***	(22.194)
lag1_log_ENST	0.95	(0.914)	1.336***	(0.056)	-5.143	(36.565)
lag2_log_ENST	-0.224	(0.563)	-0.419***	(0.056)	51.704**	(22.304)
EUM	2.263***	(0.399)	0.047	(0.044)	49.351***	(15.65)
lag1_RDEX:EUM	1.382*	(0.749)	-0.229**	(0.081)	12.372	(29.947)
lag2_RDEX:EUM	-0.801	(0.77)	0.213*	(0.084)	25.838	(30.767)
lag_EDEX:EUM	-0.514***	(0.081)	-0.005	(0.009)	-9.882***	(3.194)
Observations	280					
R2	0.813		0.937		0.492	
Adjusted R2	0.794		0.931		0.442	
F Statistic	84.535*** (df = 13; 253)		316.391*** (df = 12; 254)		20.531*** (df = 12; 254)	
Note: *p<0.1; **p<0.05; ***p<0.01						

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

In this study, we looked at how government investments in education and R&D influence ICT services exports in the CEE region. We also examined the role of enrolled students and internet infrastructure in the relationship between FDI and ICT services exports. Our analysis revealed key findings with significant implications for businesses, policymakers, and researchers.

First, our analysis results support the idea that the impact of government investments in education and R&D on ICT services exports is accentuated in EU member countries within the CEE region. Additionally, we shown a positive relationship between FDI and ICT services exports, and positive, but less decisive relationship between FDI and internet availability.

Based on these findings, we propose the following recommendations for different stakeholders:

1. To create a suitable environment for ICT services exports growth in the CEE region, policymakers should invest in education and R&D, focusing on ICT-related fields. A focus on both formal and vocational education that prepares individuals for the demands of the ICT sector can help build a skilled workforce that will fuel the industry's growth.
2. National and regional authorities should emphasize the development and maintenance of internet infrastructure to attract FDI and promote ICT exports. Policies that attract investments into high-speed internet networks and improve accessibility, especially in underdeveloped areas, will contribute positively to the ICT sector's expansion.
3. Policymakers in EU member states should leverage the benefits of EU membership, such as access to funding opportunities, policy cooperation, and broader market access, to strengthen the ICT sector and promote regional collaboration on innovative projects.

4. Businesses operating in the ICT sector should capitalize on the positive relationship between FDI and ICT services exports by actively seeking investment opportunities, forming strategic partnerships with global corporations, and exploring expansion into more developed ICT markets.
5. Researchers should continue investigating the interplay between FDI, education, R&D, and ICT services exports to provide greater insights into the drivers of growth in the ICT sector. Further analysis of the mediating role of skilled labor and internet infrastructure could provide valuable information to policymakers and industry leaders in devising targeted strategies for ICT development in the CEE region.

For future research, we suggest exploring potential variations in the relationships of interest across different countries within the CEE region and incorporating additional factors such as regulatory environment, trade policies, and intellectual property rights protection that may influence ICT services exports. Furthermore, future research could consider longitudinal analysis with time-varying effects or panel data techniques to better understand the dynamics of the relationships studied in this paper.

In conclusion, our analysis provides compelling evidence that government investments in education and R&D, as well as the benefits of EU membership, contribute positively to ICT services exports in the CEE region. By adopting targeted policies and strategies, policymakers, businesses, and researchers can work together to capitalize on these findings and drive future growth in the ICT sector.

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APPENDIX

R OUTPUTS

R Output for Table 3

```
Oneway (individual) effect Within Model

Call:
plm(formula = log(XICT) ~ lag_EDEX + lag_log_FDI + INT + log(EXRT) +
    lag1_RDEX + lag2_RDEX + lag1_log_ENST + log(ENST) + EUM +
    EUM * lag1_RDEX + EUM * lag2_RDEX + EUM * lag_EDEX, data = clean_d
ata, model = "within")

Balanced Panel: n = 14, T = 20, N = 280

Residuals:
     Min.   1st Qu.    Median   3rd Qu.      Max.
-1.752771 -0.246710  0.041511  0.253053  1.136646

Total Sum of Squares:    218.11
Residual Sum of Squares: 40.841
R-Squared:      0.81275
Adj. R-Squared: 0.79432
F-statistic: 91.871 on 12 and 254 DF, p-value: < 2.22e-16
```

R Output for Table 4

Oneway (individual) effect Random Effect Model (Swamy-Arora's transformation)

Call:
plm(formula = log(XICT) ~ lag_EDEX + lag_log_FDI + INT + log(EXRT) +
    lag1_RDEX + lag2_RDEX + lag1_log_ENST + log(ENST) + EUM +
    EUM * lag1_RDEX + EUM * lag2_RDEX + EUM * lag_EDEX, data = clean_d
ata,
    model = "random")

Balanced Panel: n = 14, T = 20, N = 280

Effects:

	var	std.dev	share
idiosyncratic	0.1608	0.4010	0.513
individual	0.1529	0.3910	0.487

theta: 0.7765

Residuals:

Min.	1st Qu.	Median	3rd Qu.	Max.
-1.811491	-0.327277	0.015555	0.325249	1.030601

Total Sum of Squares: 238.92
Residual Sum of Squares: 54.968
R-Squared: 0.76994
Adj. R-Squared: 0.7596
Chisq: 893.543 on 12 DF, p-value: $< 2.22e^{-16}$

R Output for Table 5

```
Call:
lm(formula = log(XICT) ~ lag_EDEX + lag_log_FDI + INT + log(EXRT) +
    lag1_RDEX + lag2_RDEX + lag1_log_ENST + log(ENST) + EUM +
    EUM * lag1_RDEX + EUM * lag2_RDEX + EUM * lag_EDEX, data = clean_d
ata)

Residuals:
     Min       1Q   Median       3Q      Max
-2.09354 -0.28971 -0.01287  0.40129  1.44469

Residual standard error: 0.5903 on 267 degrees of freedom
Multiple R-squared:  0.8534,  Adjusted R-squared:  0.8468
F-statistic: 129.6 on 12 and 267 DF,  p-value: < 2.2e-16
```

R Output for Table 6

```
Hausman Test

data:  log(XICT) ~ lag_EDEX + lag_log_FDI + INT + log(EXRT) + lag1_RDEX
+  ...

chisq = 90.852, df = 12, p-value = 3.377e-14
alternative hypothesis: one model is inconsistent
```

R Output for Table 7

```
F test for individual effects

data:  log(XICT) ~ lag_EDEX + lag_log_FDI + INT + log(EXRT) + lag1_RDEX
+  ...

F = 24.975, df1 = 13, df2 = 254, p-value < 2.2e-16
alternative hypothesis: significant effects
```

R Output for Table 8

Dependent variable:	log(XICT)	log(ENST)	INT
	(1)	(2)	(3)
lag_EDEX	0.362***	0.006	5.798***
	(0.055)	(0.006)	(2.176)
lag_log_FDI	0.011	-0.0003	0.043
	(0.017)	(0.002)	(0.666)
INT	0.028***	-0.001***	
	(0.002)	(0.0002)	
log(EXRT)	-0.011	0.003	2.665**
	(0.033)	(0.004)	(1.324)
lag1_RDEX	-0.914	0.215***	10.999
	(0.671)	(0.073)	(26.837)
lag2_RDEX	0.558	-0.240***	-37.169
	(0.691)	(0.075)	(27.572)
log(ENST)	-1.749***		-79.737***
	(0.569)		(22.194)
lag1_log_ENST	0.950	1.336***	-5.143
	(0.914)	(0.056)	(36.565)
lag2_log_ENST	-0.224	-0.419***	51.704**
	(0.563)	(0.056)	(22.304)
EUM	2.263***	0.047	49.351***
	(0.399)	(0.044)	(15.650)
lag1_RDEX:EUM	1.382*	-0.229***	12.372
	(0.749)	(0.081)	(29.947)
lag2_RDEX:EUM	-0.801	0.213**	25.838
	(0.770)	(0.084)	(30.767)
lag_EDEX:EUM	-0.514***	-0.005	-9.882***
	(0.081)	(0.009)	(3.194)
Observations	280	280	280
R2	0.813	0.937	0.492
Adjusted R2	0.794	0.931	0.442
F Statistic	84.535***	316.391***	20.531***
	(df = 13; 253)	(df = 12; 254)	(df = 12; 254)

Note: *p<0.1; **p<0.05; ***p<0.01