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Shaping Employment through Digital Transformation: Beyond Broadband and Security in Central and Eastern Europe

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Abstract. *Digital technology has been incorporated into economies in such a way that transforms the very dynamics of labor markets. The most unprecedented forms that influence employment have been broadband expansion supported by wide-spread belief. Even with expansiveness in broadband, the potential effect of secure internet infrastructures on labor market outcomes is not fully understood. This paper tries to analyze the relationship between broadband penetration, secure online infrastructure, and employment in Central and Eastern Europe focusing on Hungary, Poland, and Romania. Existing research directly links digitalization with increased connectivity plus innovation-driven employment. More poorly analyzed aspects see secure digital environments as advancing labor markets by enabling digital entrepreneurship through higher trust levels in online transactions plus support for knowledge-intensive industry responding to its needs. This study attempts to further the understanding of digital transformation by analyzing to what extent secure online systems and general internet availability facilitate employment transformation. It is attempted in this paper to demonstrate the relationship between broad usage, secure digital systems, and employment trends over a decade with an econometric method using a multi-factor regression model. Country-level variations are where this paper estimates the magnitude factors of digitization for different labor changes; thus, this study contributes to the discussion on digital transformation by indicating how connectivity and security requirements together constitute one approach in predicting impacts and making their adjustments in labor markets. The findings therein give an appropriate direction for policymakers and business leaders who want to ensure that labor market dynamics remain buoyant while ushering in the new digital economy.*

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Introduction

Over the last several years, the great shift in the global economy encouraging a wide-band internet revolution that creates vast connections and information availability with labor markets and industries. This restructuring will embed itself more profoundly as time passes; therefore, security of those places will be at the top of the economic and employment trend lists.

Broadband penetration has a large number of studies that focus on it. Certainly, fast internet supports a more productive working environment and encourages innovation and hence new business models that can sustain enterprises and jobs. Broadband expansion in Norway increased the rates at which unemployed workers found jobs Bhuller et al., 2019). Further evidence Köppl-Turyna et al., 2019) exists to support positive impacts of broadband availability on employment growth within German establishments. However, very little is known about how digital security infrastructure impacts the labor market. Eventually, as economies become more digital, data and transaction security will come up. Rather than saving jobs so well in it, strong cybersecurity creates trust for online spaces through which e-commerce and other internet services can grow. The Organisation for Economic Co-operation and Development gives more focus to the changes of cybersecurity skill needs that falls far behind in the European countries (OECD, 2024).

Hungary, Poland and Romania are countries located in Central and Eastern Europe presently undergoing significant dynamism marked by digital transition. The digital economies of these countries can scale very fast sometimes even outpace their Western European counterparts (Piatkowski et al., 2020). Such growth may bring opportunities and challenges specific to the development of digital infrastructure and labor market implications. Although considered crucial, connectivity and security have not been researched on their joint impacts on the workforce of CEE. Drawing how broadband penetration and at the same time digital security infrastructure jointly affect labor markets would be very instrumental in such critical decision-making contexts concerning policy choices and strategic investments. This paper introduces that relationship undertakes a similar analysis for Hungary, Poland, Romania.

Using an econometric approach, data beginning in 2014 up until 2023 is run through a multifactorial regression model in this paper. So, to what extent can or cannot broadband access and secure internet infrastructure drive employment growth or restructuring of the labor market in these particular countries? That raises another issue: cross-country diversity at the very nuanced effects of digital infrastructure on employment dynamics; hence it is what this paper tries to bring out. Hence, that should be the results hence very valuable for the policy, business, and other stakeholder communities of the CEE region based on this study. The research reiterates an element that has been yearning for extensive digital strategies concerning both halves- connectivity and security- which in turn are required to build the resilience as well as inclusiveness of labor markets.

The remaining part of this paper is organized as follows. Related literature is presented in the second section of this paper. Methodology, which includes data sources and techniques of econometric modeling, is discussed in Section 3. An analysis of empirical results will be conducted in Section 4, along with its probable implications. The final section-Section 5- ends the paper by summarizing the results and recommending policies, along with suggesting further arenas of research.

Literature review

The changing dynamics of the evolving process have, to the greatest extent, impacted different labor markets across the world but, most of all, the Central and Eastern Europe (CEE) region. To respond closely to the fast-evolving relations, the paper focuses on the critical nexus between broadband penetration, digital security infrastructure, and labor market trends in Hungary, Poland, and Romania.

Broadband has also been identified to have a very positive effect on economic growth and job creation. Results of the European Corporate Sector Development show precisely how innovation indicators and broadband availability are positively correlated (enterprise offering ICT training, and knowledge- intensive service exports), it carries out by Leogrande, Costantiello, & Laureti (2021). This implies that through broadband infrastructure, an important channel which promotes an environment where innovation can bear fruits and employment grow is established.

Hungary has seen huge advances in the provision of broadband services. Broadband penetration in Hungary went up a lot between 2005 and 2010, showing that digital infrastructure had improved greatly (Pápai, 2010). The pace of change most likely played some role in better labor market outcomes via faster availability of knowledge, access to information through various channels, and new business models. The digital landscape in Poland has changed as well since investment is a key factor in broadband infrastructure. Studies have shown that broadband expansion, particularly funded by EU Structural Funds, has positive impacts on regional cohesion and economic activities within Poland and other new member states(Kulková, 2012). Most probably such investments have increased employment opportunities also because better connectivity and lower the digital divides would translate into better employment. Romania is getting better, but its digital infrastructure stays behind the more developed Western European countries. In a report put together by them, the International Monetary Fund [IMF] (2020) pointed out how the lag of Central, Eastern and Southeastern European countries including Romania in this aspect against Western Europe could hold back potential job gains that come from digital links.

The digital security infrastructure is therefore making connectivity and labor markets at the same time. The Organisation for Economic Co-operation and Development (OECD, 2024) indicated a very huge demand for cybersecurity skills in Europe with significant gaps in the workforce. A good cybersecurity framework protects existing jobs and also creates new jobs by raising confidence in digital platforms, hence further boosting e-commerce and online services. Additionally, this relationship between digitalization and employment cannot be assumed to be unidirectional. Even as broadband penetration may lead to innovation and job creation, quality and safety of the digital infrastructure also matter. For example, increased employment opportunities were more related to expansion of broadband in Hungary. However, investment in secure servers is what sometimes leads to job displacement in the formal sector because of automation (Leogrande et al., 2021).

In Poland, outcomes appear to be more concentrated on employment if we compare them with broadband, impacts from digital security infrastructures. Investment in secure IT environments is very related to the growth of the digital economy and jobs created therein; hence, cybersecurity will be a key issue in modern labor markets. The Romanian business environment, fairly unmolested by cybersecurity breaches, has recently been thriving and creating new jobs within the remote digital work field. All this support is meant to secure economic growth and job creation in the longer term through the need for skilled workforce enhancement in cybersecurity.

The pandemic has greatly accelerated the process of digitization, more so intensified the need for strong digital infrastructures and digital-ready workforces. An ILO (2020) study provides

a development narrative on how Eastern Europe digital labor markets evolved during pandemics, focusing on the speedy expansion of online labor platforms and applications. From this wave, new forms of employment have emerged, flexibly spirited, in their wake come insecurity of work and challenges surrounding the conditions under which work is done. The pandemic made explicit demand for digital skills in the labor market (Trașcă et al., 2019). The impact of digitalization on employment is twofold. It creates jobs—new business models and products—but also has the potential to eliminate jobs through automation (European Parliament, 2017). This duality warrants truly comprehensive policy responses that will leverage the benefits of digitalization and mitigate its adverse effects (Vargas et.al., 2022).

Broadband, Digital Security Infrastructure, and Employment are discussed in a paper that brings out their interrelationships in countries of Central and Eastern Europe. Broadband creates the environment for interfaces—both as a factor of security and quality of digital infrastructure it has an employment outcome. Legislators should mandate investment in connectivity to be achieved by adequate cybersecurity along with reskilling workers to maximize the employment benefits from the transformation to digitalization.

Methodology

This paper initiates a quantitative research design that deals with the analysis of the relationship between digital infrastructure and employment in Romania, Poland, and Hungary-three economies from Central and Eastern Europe. It tries to determine through a multiple linear regression model the direct influence that broadband penetration and secure internet infrastructure have on total employment within these three economies. The major goal is to determine whether this kind of digital connectivity plus cybersecurity infrastructure does substantially contribute to the process of expansion in the labor market as well as economic growth.

The dataset originated as amalgamated info-ware from the World Bank and OECD databanks between 2014-2023. Here, the last year is taken to be 2023 based on available data to attain the most up-to-date and applicable economic indicators. For applied economic measures in this study, data sources need to be cited in a uniform and consistent manner from reputable international databases whereby single methodology adherence creates homogeneity of comparability.

The equation of the **multiple regression model (1)** is, therefore:

$$Y=\alpha+\beta_1 X_1+\beta_2 X_2+\varepsilon \quad \textbf{(1)}$$

In this work, total employment (thousands of persons, aged 20-64), denoted by Y, describes the labor market situation in Hungary, Poland, and Romania. Two explanatory variables were assigned to the model in explaining how digital infrastructural development influences employment. The first is X_1 which denotes broadband subscriptions per country expressed in absolute numbers hence determining the extent of digital connectivity available to enterprises and households. The second is X_2 absolute numbers of secure internet servers per country standing proxy for digital security infrastructure and its role in creating a secure and trustworthy digital environment.

The α value shows the basic level of employment without internet use. β_1 , β_2 values control how much broadband penetration and secure internet servers affect total employment, but it only tells the direction in which the change would influence total employment, i.e., positively or negatively to the growth of the labor market. Last, ε (the error term) includes all unobserved factors

at play in pushing the overall trend of employment over and above the forces modeled, such as outside economic or technological forces.

The study model is Multiple Linear Regression Estimated by Ordinary Least Squares (OLS). OLS makes sure the estimates are unbiased and statistically efficient. Econometric analysis is carried out in EViews. The software performs exceptionally well with manipulation of time-series data while allowing confirmation of the statistical validity of relationships between digital infrastructure and employment. It validates these relationships by using tests of R-squared and the F-statistic plus the estimation process to determine if different values of broadband penetration and cybersecurity infrastructure really influence employment. How well digital indicators explain variations in employment are better reflected by R-squared values, while the overall significance of the regression model in explaining labor market trends is summarized by the F-statistics.

This study helps work out comparative descriptions of Hungary, Poland, and Romania to find out how digital infrastructures have been influencing employment patterns. Pertaining to economic debates on digital transformations, it proves the capacity to work as a stimulator of the labor market, provided that this study ensures estimations that are robust and statistically sound. It will follow with recommendations for policies for the governments and business leaders in the European Region to guide decisions regarding investment in digital infrastructure and upskilling the workforce to sustain the growth of employment in the longer-run perspective.

Results and discussions

The data in Table 1 reflect the dynamics of total employment, fixed broadband subscriptions, and secure internet servers in Romania, Poland, and Hungary from 2014 to 2023. These indicators are assumed to imitate some elements of the transformation of the digital sphere; hence, correlation with the probable dynamics of the labor market can be assumed. The data are based on the sources of the World Bank and Eurostat and indeed prove massive development of digital infrastructure, with first place taken by the absolute extension of broadband access and secure online services with employment trends.

Table 1. The Digitalization and Employment Nexus: Analyzing Trends in Romania, Poland, and Hungary (2014-2023)

Year	Romania		
	Total employment (th. persons 20-64)	Fixed broadband subscriptions (no.)	Secure Internet servers (no.)
2014	7218	4020000	4912
2015	7298	4260000	7158
2016	7349	4450000	67411
2017	7540	4750000	240048
2018	7581	5090000	310378
2019	7638	5280000	371250
2020	7547	5680000	411782
2021	7625	6100000	445866
2022	7686	6370000	471223
2023	7568	6630000	511496
Year	Poland		
	Total employment (th. persons 20-64)	Fixed broadband subscriptions (no.)	Secure Internet servers (no.)
2014	15142	7230000	25891
2015	15406	7270000	36309
2016	15565	7330000	94640
2017	15789	7630000	248163

Year	Poland		
	Total employment (th. persons 20-64)	Fixed broadband subscriptions (no.)	Secure Internet servers (no.)
2018	15875	7850000	616219
2019	16305	7840000	782319
2020	16288	8370000	954351
2021	16672	8680000	1161013
2022	16735	9150000	1280389
2023	16776	10100000	1369941
Year	Hungary		
	Total employment (th. persons 20-64)	Fixed broadband subscriptions (no.)	Secure Internet servers (no.)
2014	4174	2580000	6592
2015	4278	2720000	9120
2016	4415	2810000	40492
2017	4474	2960000	133382
2018	4509	3080000	188120
2019	4520	3190000	256400
2020	4462	3270000	319932
2021	4488	3380000	405489
2022	4536	3540000	493765
2023	4551	3560000	515271

Source: The World Bank, World Development Indicators, Eurostat Database [Accessed 17 February 2025].

Data for fixed broadband subscriptions show steady growing figures, though very sharp multiplied numbers of secure internet servers in all countries indicate very apparent improvements in digital connectivity and cybersecurity infrastructure. While employment levels have generally moved upwards, there have been some fluctuations, thus hinting that potential biases lie in broader economic factors such as technological progress, labor market policies, or external shocks. Thus, the analysis of these indicators will help explore the interplay between indicators of digitalization and employment phenomena with all possibilities for how the growth of internet infrastructure manifests in changes in the level of participation in the labor force.

Table 2. Digital Infrastructure and Employment in Romania: A Regression Perspective

Dependent Variable: Total employment (th. persons 20-64)
Method: Least Squares
Included observations: 10

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-7700.407	296.7289	26.28462	0.0000
Fixed broadband subscriptions (no.)	-0.000127	7.39E-05	-1.723278	0.1285
Secure Internet servers (no.)	0.001322	0.000346	3.821649	0.0065
R-squared	0.893200	Mean dependent var		7505.000
Adjusted R-squared	0.862686	S.D. dependent var		158.8633
S.E. of regression	58.86827	Akaike info criterion		11.23181
Sum squared resid	24258.31	Schwarz criterion		11.32258
Log likelihood	-53.15903	Hannan-Quinn criteria.		11.13223
F-statistic	29.27157	Durbin-Watson stat		2.094690
Prob(F-statistic)	0.000398			

Source: Authors' own data processing in eViews, based on the data from Table 1

For Romania, the regression of total employment (20-64 years) on the two leading indicators of digitalization, which are fixed broadband subscriptions and secure internet servers, results in a model that indicates a very high explanatory power of 0.89 for R-squared, meaning that approximately 89% of variations in employment can be explained by these two proxies. The adjusted R-squared is 0.86, and thus this high power drops slightly, given the number of available observations and degrees of freedom. The f statistic is additional, very significant at 29.27 ($p = 0.000398$).

For the individual coefficients, secure internet servers reveal a statistically positive coefficient ($\beta = 0.001322$, $p = 0.0065$) in higher employment levels. Confidence in business, and at a lower magnitude, stimulation for e-commerce, can be conducted in investments of economic activities that create jobs via a more securely digitalized environment. On the opposite side, fixed broadband subscriptions provide a negative β value (-0.000127); the impact is not significant ($p = 0.1285$). This result may indicate either the expansion on broadband does not go straight on inducing for job creation or the indirect channels, such as labor market flexibility and digital acumen, have to be considered in finding a relationship with job creation.

Results from the study revealed that the level of employment in Romania benefitted more from a change in digital security than from the extension of broadband, though the former alone. While fixed broadband is said to be imperative for digital transformation, its impact, if any, will be reflected in employment, and moreover the effect is long run. These results give reason that policy should be such design that to complement the internet access with cybersecurity and digital skills as well as innovation-based jobs.

Table 3. Digital Infrastructure and Employment in Poland: A Regression Perspective

Dependent Variable: Total employment (th. persons 20-64)
Method: Least Squares
Included observations: 10

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	15647.54	945.6433	16.54698	0.0000
Fixed broadband subscriptions (no.)	-4.25E-05	0.000133	-0.318578	0.7593
Secure Internet servers (no.)	0.001147	0.000236	4.870341	0.0018
R-squared	0.953337	Mean dependent var		16055.30
Adjusted R-squared	0.940005	S.D. dependent var		584.7834
S.E. of regression	143.2366	Akaike info criterion		13.01020
Sum squared resid	143617.0	Schwarz criterion		13.10097
Log likelihood	-62.05099	Hannan-Quinn criteria.		12.91062
F-statistic	71.50578	Durbin-Watson stat		2.13633
Prob(F-statistic)	0.000022			

Source: Authors' own data processing in Eviews, based on the data from Table 1.

For Poland, digitalization is shown through the regression analysis of total employment change. Fixed broadband and secure internet servers are taken as independent variables. An R-squared value of 0.95 implies that the choice of indicators for digitalization explains about 95% of variations in employment. The statistics given here for this model, $F = 71.51$, $p = 0.000022$,

unquestionably validates it strong statistical significance; adjusted R-squared also confirms that this model to be like very reliable at 0.94 alongside degrees of freedom.

A further detailed breakdown shows that the coefficient of Poland's secure internet servers on employment is statistically significant and positive (β = 0.001147, p = 0.0018). This means that digital security infrastructure improvements have somewhat related to increased trust in online transactions leading to business expansion and the strong contribution that digital services provide to the Polish economy and hence on employment growth which is quite high in magnitude. On the other side, fixed broadband subscriptions have slightly negative effects with a coefficient of (β = -4.25E-05) but the effects are statistically insignificant (p = 0.7593). This means that diffusion alone does not have a direct impact on employment growth; it requires some complementary factors like promotion regarding digital skills and adaptation by enterprise.

On the other hand, there is a great deal of optimistic proof of the impacts of the building up of cybersecurity infrastructure on the job market in Poland. So, this will underline even more how important a safe digital environment is for fostering economic growth and increasing employment opportunities. While high-speed internet access stays in the list of basic supporting elements for digitalization itself, its impacts on employment might rely on other more general socio-economic factors. These findings highlight the demand for holistic policies aimed not just at increasing access to the web but also at improving awareness regarding cybersecurity as well as readiness for the emerging digital economy.

Table 4. Digital Infrastructure and Employment in Hungary: A Regression Perspective

Dependent Variable: Total employment (th. persons 20-64)
Method: Least Squares
Included observations: 10

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	774.1205	575.3633	1.345446	0.2204
Fixed broadband subscriptions (no.)	0.001316	0.000213	6.175543	0.0005
Secure Internet servers (no.)	-0.001799	0.000374	-4.798824	0.0020
R-squared	0.936571	Mean dependent var		4440.700
Adjusted R-squared	0.918448	S.D. dependent var		122.1393
S.E. of regression	34.87974	Akaike info criterion		10.18501
Sum squared resid	8516.175	Schwarz criterion		10.27579
Log likelihood	-47.92507	Hannan-Quinn criteria.		10.08543
F-statistic	51.67939	Durbin-Watson stat		2.031225
Prob(F-statistic)	0.000064			

Source: Authors' own data processing in eViews, based on the data from Table 1.

The model shows a fairly strong explanation of the relation between total employment (ages 20-64) with fixed broadband subscriptions and the number of secure internet servers in Hungary. It gives an R-squared value of 0.94 meaning that 93.7% of the variations in employment are explained by the independent variables. Taking into account the F value for overall model significance (51.68 with p = 0.000064) as well as a rather high adjusted R-squared value (0.92) for reliability once controlling for the number of observations, one can say that this model is statistically significant.

Contrary to Romania and Poland, fixed broadband subscriptions have a positive and statistically significant relationship with employment in the case of Bulgaria ($\beta = 0.001316$, $p = 0.0005$). This means increased access to broadband has also contributed to job creation, presumably through enabling digitalization of businesses, remote work, and new economic opportunities. However, secure internet servers have a negative and significant relationship with employment ($\beta = -0.001799$, $p = 0.0020$), an atypical finding. This implies that increased cybersecurity measures could possibly lead to automation replacing some labor-intensive processes or that digitalization is inducing a structural change in the labor market toward more skilled workforces with falling demand for labor in conventional jobs.

Overall, Hungarian workforce patterns show both effects of digitalization: expansion seems to assist in encouraging employment even though secure internet servers are positively related to increasing employment because it is negatively related due to automation or structural economic changes. This implies that while digital infrastructure is instrumental in driving economic development, policies have to focus more on workforce adaptation, that is ensuring digitalization promotes employment growth in a creative way rather than simply removing certain categories of jobs.

Conclusion

The cases of Romania, Poland, and Hungary demonstrate that its impact on employment varies from economy to economy. While in most cases, a link is made between the spread of broadband and the economic process, its direct effect on job creation is still somewhat unclear. On the other, secure online infrastructure turns out to be one of the more potential factors for labor market resilience towards digital economic activities. Results highlight how digitalization supports employment but it is dependent on the country and how highly digitized it is as well as the structure of the economy what will determine everything.

Secure internet infrastructure in Romania supports needs in increasing employment, strengthening business confidence, e-commerce, and knowledge sectors. There was no historic impact of broadband expansion on employment directly, it can be said that pushing internet access alone was not enough without other policies that would enhance digital skills and encourage adoption by businesses. This is the situation in Poland; however strong is the relationship between secure internet servers and employment growth cybersecurity proves its importance. While there is little direct effect from broadband expansion there is a strong need for workforce adaptation strategy for effective digitalization.

Hungary presents a contrasting scenario since, in that country, broadband rollout goes on to significantly contribute to employment growth. Thus, the negative linkage of secured internet infrastructure with employment indicates that automation and digitalization are taking away traditional jobs; therefore, this raises an alarm in the eyes of policymakers on the imperative need for a proper balance between technological advancement and the quest for job preservation through reskilling, upskilling, and adapting the workforce. Policies should protect investments in cybersecurity as well as those closing digital skills gaps and supporting digital entrepreneurship.

The management of impacts from both inclusive digitalization affecting rural areas and automation affecting labor markets holds significance. National strategies have to be redirected toward adjustments that would align both connectivity plus security focus areas to build an agile digital transformation workforce.

Future research should focus long-term effects in the whole process digitalization in employment is further investigated, particularly area Mekotke development automation, building security, enhancing human capital development.

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