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Enhancing women's engagement in economic activities through information and communication technology deployment: Evidence from Central-Eastern European countries

This study takes a macro perspective to examine the associations between the economic deployment of information and communication technology (ICT), women`s labor market participation, and economic growth in Central-Eastern European countries between 1990 and 2017. We use data extracted from World Bank Development Indicators, World Development Reports, and the *World Telecommunication/ICT Indicators Database*. Our methodological framework combines time trends, graphical non-parametric analysis, and panel vector-autoregressive models. The findings reveal significant relationships between ICT and women's economic activity. Panel vector-auto-regression model estimates and Granger causality tests indicate causal relationships between ICT, economic growth, and female youth employment but not between the remaining pairs of variables.

Keywords: Central-Eastern Europe, economic growth, engagement, ICT, information and communication technology, women

JEL Classification: O30, O40

1. Introduction

Central-Eastern European countries (CEECs) experienced a rapid diffusion of information and communication technologies (ICTs) between 1990 and 2017, which triggered profound changes and structural shifts. General purpose technologies (Bresnahan & Trajtenberg, 1995), ICTs are "enabling technologies" that create networks (Castells, 2009), enhance exchanges of information and knowledge, and reshape how people communicate and run businesses. The growing role of ICT in reinforcing structural changes is demonstrated not only through changes in the structure of production and employment but also through shifts in the composition of the labor force (González et al., 2016; Jorgenson et al., 2016).

In CEECs the transition from centrally planned to market economies implied changes in labor markets (Mason, 2018). At the beginning of the transition period, labor demand rapidly collapsed; the region experienced falling employment rates and growing unemployment, accompanied by a modest decline in real wages, and both effects were clearly observable among women (Bell & Mickiewicz, 2013). The persistence of traditional gender roles, combined with the relatively low supply of flexible forms of employment, forced women to concentrate in semiskilled professional occupations in sectors such as health care, education, and retail (Verme, 2017). This situation helped increase the wage gap between the male and female populations.

The number of women discouraged by the "male-oriented labor market" was relatively high (Pignatti, 2016). Most CEECs are now experiencing rapid economic change, including an increase in women's engagement in the formal labor market. The growing role of ICT may be an important factor in enhancing female labor force participation, by making the labor market more flexible. New technologies, digitalization, and artificial intelligence are revolutionizing how work gets done. Fostering gender equality in this changing labor landscape has become an imperative across the globe, not only for CEECs (Dvornik & Sabolić, 2007).[1] Women may benefit from this situation only if investments in education are made to enable them to perform more abstract and less-routine tasks (Autor et al., 2003). Dell'Anno and Solomon (2014) argue that the benefits of digitalization are greater for highly skilled workers and that, more generally, growing technological deployment may foster women's economic engagement—by which we mean women's active participation in economic life, especially their engagement in labor market activities and education, which leads to growth in per capita income. This is conceptually associated with the broader concept of women's economic empowerment. Women's economic engagement— which involves the elimination of the barriers and constrains preventing women from participation in economic life, the labor market, and education activities—contributes to a more just distribution of economic power and possibilities, as well as of access to and control over financial resources (Alsop & Heinsohn, 2005; Duflo, 2012), thus enhancing per capita income. Tornqvist and Schmitz (2009) argue that women's economic engagement is achievable through unrestricted access to economic resources and opportunities via the elimination of gender inequalities in the labor market.

We hypothesize that increasing ICT usage enhances women's engagement in the labor market. This study has three research targets:

(1) We trace changes in women's labor market engagement across CEECs countries;

[1] The global female labor force participation rate (age group 15+) declined from 51.3% in 1998 to 48.5% in 2018 despite strong growth in emerging and developing countries. Projections suggest that female labor force participation rates will continue to fall over the coming decade or so, reaching a low of 45.9% in 2030 (ILO modelled estimates; http://www.ilo.org/ilostat [accessed February 2019]).

(2) We examine the statistical relationship between growing ICT use and changes in women's labor market engagement;

(3) We verify hypotheses regarding how the growing use of ICT impacts women's labor market engagement in several CEECs.

Our empirical sample comprises eight CEECs: Bulgaria, the Czech Republic, Hungary, Moldova, Poland, Romania, the Slovak Republic, and Ukraine. The analysis period is 1990 to 2017. All the statistical data are extracted from the *World Telecommunication/ICT Indicators Database 2018*, the World Development Indicators 2019, and the *Eurostat* database 2019.

The rest of this paper is organized as follows. Section 2 contextualizes the research, presents the main arguments, and briefly reviews the related literature. Section 3 describes the study's research method, while Section 4 discusses the data. Section 5 presents the results of the numerical analysis and interprets and discusses the outcomes. Finally, Section 6 concludes the paper.

2. Context and background

The theoretical and empirical evidence tracing the determinants of women's economic (especially labor market) engagement is broad, and its scope ranges across various disciplines (Pignatti et al., 2017). Among the long-term determinants of women's economic engagement, the International Labor Organization (ILO) and the World Bank (WB) cite demographic trends such as the decline in fertility rates and aging populations, emphasizing the importance of cultural and social norms and values. Perceptions of gender roles are key among these cultural and social aspects. Research shows a negative association between traditional gender roles and female employment rates (Fernandez & Fogli, 2006; World Bank, 2011). Moreover, economic changes and globalization are creating challenges for women. For instance, crisis and transition processes may negatively impact female employment, while globalization may drive increases in female labor force participation (World Bank, 2011). However, women may be deprived of a full ability to participate in economic life for other reasons, such as a lack of education, skills, and access to financial systems or permanent income from contracted work (Kasearu et al., 2017). In rural and less-developed regions with traditional societies, social norms and attitudes often consign the female population to "hidden and unpaid" labor. Women are intensively engaged in informal home-based businesses, serving as unpaid family workers, which require less seed capital and professional experience and that have lower returns and profits. Women operating outside the formal economy, who work home-based jobs, or who are self-employed are highly exposed to risk and external shocks (Schwander, 2019). Even in high-income countries, where the female population seems to be treated equally, national statistics demonstrate relatively large gender wage gaps (Majchrowska & Strawiński, 2018; Schneebaum et al., 2018).

In CEECs, the transition period of the early 1990s brought profound unemployment and a decline in economic activity. In these circumstances, barriers to female labor force participation has complex causes. The drop in economic output, the end of state socialism, and the transition to the free market economy had negative impacts on employment, although a slight recovery was observable after 2000. During this transition period, CEECs placed less emphasis on women-enabling policies that allowed them to combine professional work and family duties. Hence, women's labor force participation did not recover during the early transition period. Before systemic changes occurred, these countries were characterized by excess of labor demand, a lack of official unemployment, and high labor force participation (Lehmann & Muravyev, 2011). This overemployment was a direct consequence of an ineffective labor force use under centrally planned economies. Authoritarian governments promoted the dual-earner family model, wherein women were burdened with both full-time paid employment and unpaid household responsibilities (Motiejūnaitė, 2010); this disappeared during the transition period. Consequently, the female labor participation rate dropped from 53.7% in 1992 to 47.9% in 2003, while the male rate dropped from 69.9% to 62.4%. The growing unemployment affected women more heavily: More than half of the jobs lost in the region had been held by women (Esim, 2001), and the expansion of private services benefited men more than women, whose proportion of employment in this sector decreased from between half and two-thirds in 1990 to less than half in 2001 (Pollert, 2005). The wage gap in the communist period reflected job segregation, with men working in the better-paid, heavy, "core" industries and women working in poorly paid "peripheral" or "light" industries, services, and administration (Pollert, 2003, p. 332). In 2001, the CEECs' pay gap was still wider than that of the EU-15 (EC, 2003, p. 12); the difference was largest in the industrial sector, where women earned only 74% of man's pay (Pollert, 2005). A very low labor flexibility, an absence of part-time positions, and traditional perceptions of gender roles were key barriers to a greater inclusion of women in the labor market. During the market-oriented transition, political attempts were made to retraditionalize the family institution, resulting in the loss of security and a decreasing quality of public services. Cultural and religious pressures have strengthened conservative gender role models, assigning men to active professional careers and women to the private life of housework and motherhood (Bracewell, 1996; Bradić-Vuković et al., 2007). Policies governing child bearing and rearing, strongly determined by this conservative perception of the woman as the main caretaker of children and the elderly, have deepened gender inequalities in the labor market while paradoxically also leading to higher rates of poverty among women. The CEEC region often features poor female participation in formal economic activities, the labor market, or entrepreneurial activities (Avlijaš, 2019; Flek & Mysíková, 2015). This weaker female economic activity relative to that in high-income countries may be a negative effect of impeded access to education and poorly developed professional skills (Aisa et al., 2019; Fodor & Horn, 2015; Rueschemeyer, 2016). Nevertheless, the number of women running their own businesses in CEECs has gradually increased since the 1990s; in many economies, however, the main motivation for women to set up a new business is necessity, not opportunity (Christiansen et al., 2018; Momsen, 2018); it is their only viable option given the absence of alternative ways of supplementing household income or engaging in entrepreneurship or self-employment.

In educational terms, the CEECs' transformation period has oscillated between chaos and stability. The beginning was marked by extreme disorder caused by general economic upheaval and painful reforms, after which educational institutions started to stabilize (Kogan & Unt, 2005). Most of the sample countries display no radical gender differences in access to tertiary education.

A growing body of literature claims that technology, particularly ICT, is shaping and changing female labor force participation (Acemoglu & Restrepo, 2017; Wajcman, 2010). A vast number of studies argue that ICT has a positive effect on female participation in the labor market (Nikulin, 2017). As ICT becomes a key element in the global economy, it offers women broad opportunities for engagement (Jiménez & Zheng, 2018). Women's labor and entrepreneurial potential as an "untapped resource" can be unlocked via ICT deployment, mainly by making it easier to overcome various gender-specific constraints on economic activities (Andersson & Hatakka, 2017;

Fielden et al., 2000). The deployment of ICT may help women attain higher literacy and obtain education and professional training, which would enable women to become active participants in the formal economy (Cornwall, 2016). Using ICT helps women to access healthcare systems and financial services and to become more economically engaged (Buvinic & Furst-Nichols, 2014). Technological advances can have direct and indirect effects on social development by mobilizing resources and reinforcing market activities; ICT may enhance the mobilization of savings and offer opportunities to convert these savings into investments; it also facilitates the mobilization of the labor force and financial resources (Pradhan et al., 2018; Stanley et al., 2018). Increasing active engagement in formal labor markets builds a solid base for earning a regular income and becoming a salaried worker, which in turn reduces employment vulnerability and exposure to negative external shocks (Asongu & Nwachukwu, 2018). Higher female participation in the labor force is likely to be one of the most important manifestations of ICT's enhancement of economic growth and development. Information and communication technology may indirectly become an effective driver of social development by improving access to education and knowledge and improving the functioning of healthcare systems. The economy- and society-wide deployment of ICT offers new opportunities to intensify business activities, internationalize companies, and enhance penetration into new markets—for example, through e-platforms. Scholars have argued that ICT usage increases storability and tradability (e.g., Boden & Miles, 2000) thereby fostering the emergence of a service-based economy. The growing deployment of ICT and increasing demand for modern, innovative services, accompanied by a massive robotization and automation of production processes (Acemoglu & Restrepo, 2018), will make economies more service-based; this seems to be one of the manifestations of the growing importance of the Digital Revolution.

The empirical evidence on the causal and statistical links between technological progress and female labor participation is growing but sparse. Alves and Steiner (2017) study data on 23 advanced economies between 1986 and 2017 to trace the causal mechanisms between women empowerment, globalization, and new opportunities arising from access to information via ICT development. Using ILO data on labor force participation and ITU data on Internet access, they link digital literacy with greater female economic and political participation, finding that growing ICT usage positively impacts women's labor force participation in upper middle-income countries. Jansson and Nahtman (2017) use a classical growth model to examine how technology leads to higher labor force participation and economic growth by increasing knowledge accumulation and educational attainment. They study data on 26 European countries covering 29 years (1981–2010) and find no significant direct causal links between technology development, labor force participation, and gross domestic product (GDP). Novák (2020) uses modern growth theories to study structural changes in central and south Eastern European countries in terms of technological changes and labor markets. Surprisingly, he finds that increases in female labor participation depresses general employment growth in all sectors, including high-tech industries. Brussevich et al. (2019) study 30 advanced and emerging economies and report that women, on average, perform more routine tasks than men, and hence that female workers are at a significantly higher risk of displacement even though technological progress has created more job opportunities for them. Petrović and Radukić (2018) study female entrepreneurship in post-transition countries, focusing on how macro-level factors such as technology and technological development affect women's engagement in labor markets and entrepreneurial activities. They find that technological factors are important in enhancing female labor activity in transition economies but that they rely on state support. Their findings are in line with the theoretical and empirical evidence presented in such seminal works as Stojanović and Vasić (2002), Welter et al. (2004), Smallbone and Welter (2009), Puffer et al. (2010), and Petrović et al. (2016). Pergelova et al. (2019) examine the impact of digital technologies on female-led small and medium-sized enterprises in Bulgaria, finding that digital technologies, especially those used in infrastructural development, are important for enhancing women's SME activities and internationalization. The works described above emphasize the importance of technological advances for labor force participation, but the empirical analyses do not unequivocally support the hypothesis that digital technologies play a positive role in labor markets. Digital technologies may enhance both male and female labor force participation while also generating other effects on labor markets, like new forms of vulnerability and displacement. Our study contributes to the discussion by broadening our understanding of the nexus between technological progress and labor force participation.

3. Methodological setting

Aside from presenting the standard descriptive statistics, our empirical strategy deploys analytical techniques that reveal the key features of the main variables and the relationships among them. We use time trend analysis and a locally weighted polynomial smoother, and we rely on panel vector autoregressive modelling techniques that allow us to capture the interdependencies in our data and trace the causality between the variables.

We construct a panel VAR model based on the same logic as that used for a standard VAR but with an added cross-sectional dimension. Suppose we have a crosssection of Y sets of units linked to each other. By definition, all the variables in a panel VAR are endogenous, so each is assumed to depend on its own lagged values plus those of all the others in the model (Dées & Guntner, 2014). A panel VAR model holds a general form:

$$\gamma_{y,t} = \nu_y + \Omega_{1,y}\Gamma_{t-1} + \cdots + \Omega_{p,y}\Gamma_{t-p} + e_{y,t} \text{ if } y = 1, \ldots \ldots, Y$$

where $\gamma_{y,t}$ denotes the $(X \times 1)$ vector of endogenous variables for the y-unit examined; t is time, and p are the lags of the endogenous variables. In the estimation procedure, we use the GMM estimator, which allows us to use Wald tests to verify the null hypothesis that one variable does not Granger-cause another (Granger, 1980). The estimation of panel VAR models requires specifying an optimal lag order (Abrigo & Love, 2016). This is typically done using model selection criteria (MSC) such as the Akaike information criteria (AIC; Akaike, 1969), Bayesian information criteria (BIC; Akaike, 1977), or the Hannan–Quinn information criteria (HQIC; Hannan & Quinn, 1979). To select the appropriate number of lags in our panel VAR models, we follow the Moment and Model Selection Criteria (MMSC) suggested by Andrews and Lu (2001). To perform model validation and draw valid conclusions from the selected panel vector-autoregression models (PVAR) models, we use the impulse-response function (IRF) to identify the response of one variable to an impulse of another, but only after checking for the stability condition of the estimated panels and performing forecast-error variance decomposition.[2]

[2] The impulse-response function (IRF) and stability condition of the estimated panels and forecast-error variance decomposition results are not reported but are available on request.

4. Empirical sample

This study examines data on eight CEECs covering 1990 to 2017 (for some countries, the time series are shorter) to trace the relationship between women's economic engagement and growing ICT use. We employ 11 variables. Internet Users ($IU_{y,t}$) is the share of a country's population that uses the Internet (data are taken from the *World Telecommunications/ICT Indicators 2018* database). This variable includes both estimates and data on the proportion of the population that uses the Internet based on national household surveys (the number should reflect the total population of the country, or at least those aged five and older; see the definition in WTI [2016]). The number of Internet users is the most commonly used measure to reflect society- and economy-wide ICT adoption and usage. It reflects the share of social members with access to new technological solutions and the opportunities they offer. The aggregated ICT data, particularly data on Internet usage, reflect changes in the overall economy and its technological development, including new technology deployment and usage, that may generate changes in areas such as demand structures, consumption patterns, and job demand (Asongu & Le Roux, 2017; Kaur et al., 2017; Niebel, 2018). Female labor is also affected by general changes in economic structure, professional preferences and opportunities, modes of doing business, and educational opportunities (Dettling, 2017; Lukács, 2020; Samargandi et al., 2019). In general, the use of the $IU_{y,t}$ variable as a proxy reflects the extent to which the Internet as an information-distribution system provides a society and economy with opportunities to reshape their structures, modes of doing business, labor engagement, and professional work methods.

Next, we use seven indicators reflecting women's participation in economic activities: the female labor force as a share of the total labor force ($Labor_{y,t}$); the female youth employment rate (the percentage of women aged 15 to 24 who are employed [Empl15-24y,t]); female employment in agriculture as a share of total female employment ($Agric_{y,t}$); female self-employment as a share of total female employment ($Self_{y,t}$); female vulnerable employment as a share of total female employment ($Vulner_{y,t}$); female contributing family workers as a share of total female employment ($Family_{y,t}$); and female wage and salaried workers as a share of total female employment ($Wage_{y,t}$). Statistics for these variables are all extracted from the International Labor Organization *ILOSTAT* database (November 2017) and rely on modelled ILO estimates. According to the ILO (2013), self-employed workers comprise own-account workers, contributing family workers, and those who work with one or a few partners or in cooperatives; their remuneration depends on the profits generated by their business. Those in vulnerable employment comprise family workers and own-account workers, who are usually employed "under relatively precarious circumstances" and are less likely to have formal work arrangements or access to benefits and social protection programs (ILO, 2013). Because contributing family workers and own-account workers are less likely to have formal work arrangements and are more at risk to economic cycles, they are categorized as "vulnerable" (ILO 2013, p. 28). We also consider a "contributing family worker" category that covers own-account workers who contribute to a "market-oriented establishment" run by another person living in the same household but who cannot be considered a business partner because their commitment to the business is "too low compared to the head of the firm." Next, the "wage and salaried worker" category comprises those who hold a type of job defined as a "paid employment job" and have employment contracts. The last indicator reflects the extent to which women are active in the total labor force. We use these seven indicators of women's participation in economic activities because they reflect macroeconomic changes in women's economic status and their ability to be actively engaged in labor markets (Su et al., 2019; Verick, 2018). Several studies report that, in transition and less-developed economies, limited access to and usage of technology and barriers to financial market ("financial exclusion") prevent women from escaping vulnerable, low-paid, and precarious employment (Altuzzara et al., 2019; Avlijas, 2016; Beneria et al., 2015; Yeager, 2018). Moreover, in turbulent times, women entrepreneurs in transitional economies tend to run home-based businesses in traditional sectors (e.g., agriculture), which are characterized by low effective demand, low profits, and high exposure to risk and external shocks (Pryer, 2017). Additionally, women are usually highly vulnerable, suffering from lower educational status than men, and their educational constrains prevent access to labor activities. Klasen (2018) and Ortiz and Pillai (2019) argue that social values and norms, the structures of national economies, and political regimes can hinder women's participation in value-added creation. Evidence of a nexus between female labor engagement and ICT deployment and usage is also traced in Schafer and Thierry (2015), González et al. (2016), Güney-Frahm (2018), Kiyota and Maruyama (2018), Krieger-Boden and Sorgner (2018), Asongu and Odhiambo (2019), and Valberg (2020), among others.

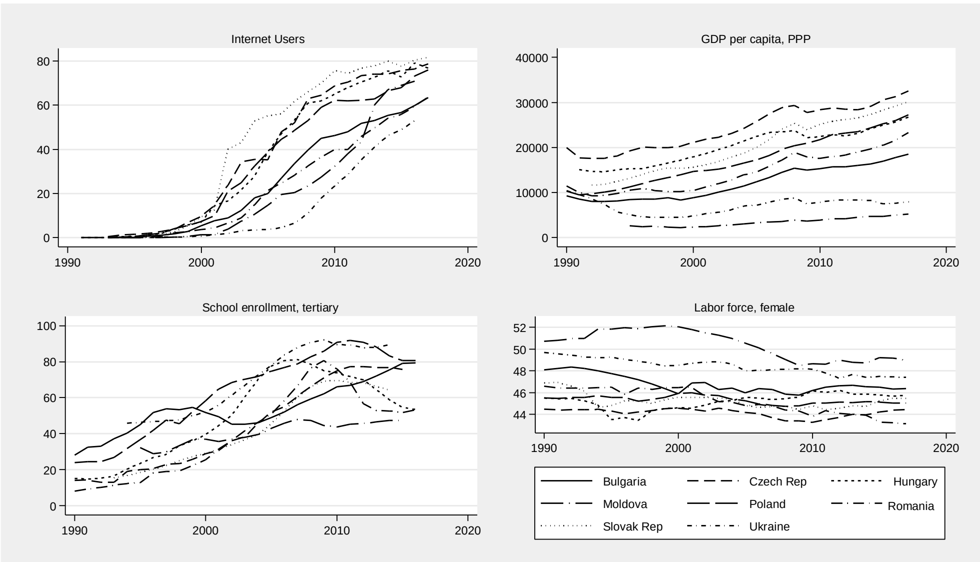
We also use three other indicators: the gender employment gap ($Gender_{y,t}$), measuring the difference between the employment rates of men and women (ages 20–64); female tertiary school enrolment as a share of total school enrolment ($SchoolTert_{y,t}$); and GDP per capita ($GDP_{y,t}$; PPP, at constant 2011 international dollars). We also control for the sectoral structure of national economies using the agriculture ($Agric_{y,t}$), industry ($Ind_{y,t}$), and services ($Serv_{y,t}$) valued added, measured as the share of GDP. The gender employment gap is calculated using data from the *EU Labor Force Survey 2019*, while the last five indicators are derived from the *World Development Indicators 2019* database.

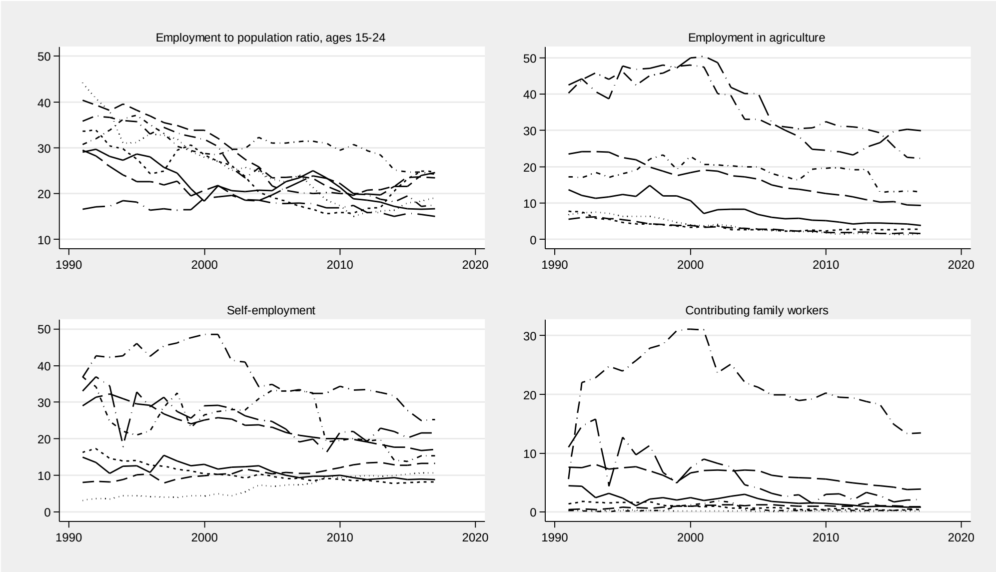
5. Research results

Descriptive and graphical evidence

In what follows, we demonstrate changes in ICT usage, approximated by $IU_{y,t}$, in $GDP_{y,t}$ and nine other variables reflecting changes in female engagement in economic activities observed across the eight CEECs between 1990 and 2017. Table 1 presents descriptive statistics, and Figure 1 enriches this picture by visualizing the changes in the main indicators.

Figure 1. Time trends: Country-wide evidence, 1990–2017





Source: Authors' elaboration.
Note: GDP on Y-axis = GDP per capita in PPP (raw data); gender employment gap on Y-axis = employment gap expressed in %pp; remaining variables on Y-axis = share of total in %.

Figure 1 reveals the country-specific time trends, showing that all the CEECs underwent profound economic changes during the study period. For all eight countries, the share of the population using the Internet grew dynamically starting in the 1990s. We observe that ICT developed slowly in the 1990s, then sped up in the early 2000s. However, considering only the period between 1990 and 2000 would give a limited picture, as growing ICT deployment was a part of the changing economic landscape in the sample countries and largely shaped current labor markets, the sectoral structures of national economies, and the effectiveness of ICT use (Meske, 2004; Radosevic, 1999). The 1990–2000 period was very turbulent; the structures of economies were changing, which increased women's labor market engagement and participation in the formal economy; ICT deployment increased quickly as well, totally reshaping the socioeconomic landscape (Andersson et al., 2009; Manea & Pearce, 2004; Meyer, 2000; Székely, 1993).

The country-specific Internet user diffusion trajectories show that this process follows a similar pattern across the countries. It is initially slow, then speeds up toward a stabilization phase. In 1991, the average $IU_{y,t}$ penetration rate was close to zero (0.3%), which grew to 73.5% over the next 26 years. Two countries in our sample, Slovakia and the Czech Republic, forged ahead in terms of Internet usage, with an IU_y of 82% and 79% in 2017, respectively. On the other hand, three countries lagged behind: Ukraine (with a $IU_{y,t}$ of 49% and Romania and Bulgaria (with an $IU_{y,t}$ of 63%). From 1990 to 2017, cross-country disparities in Internet usage decreased radially: The adjusted Gini indices[3] for 1991 and 2017 are 0.67 and 0.048. Thus, the eight CEECs followed a homogenous ICT development trajectory, and no significant cross-country differences in ICT usage are observed in 2017.

Table 1. Descriptive statistics, 1990–2017

Variable	Year	#obs.	Mean	Median	Std. Dev.	Min.	Max.
GDP per capita, PPP	1991	5	11767	9798.8	3743	8596	17740
	2017	8	21464	25045.4	10154	5190	32605
Internet users	1991	9.0	0.3	0.03	0.4	0.0	1.3

[3] Authors' calculations.

	2017	7.0	73.5	75.98	7.2	63.4	81.6
School enrolment, tertiary	1991	5.0	19.1	14.9	9.3	9.3	32.5
	2017	8.0	68.5	69.9	15.1	47.3	89.5
Labor force, female	1991	5.0	47.2	46.7	9.3	9.3	32.5
	2017	8.0	45.8	45.6	15.1	47.3	89.5
Employment to population ratio, ages 15–24	1991	8.0	32.5	32.2	8.3	16.6	44.2
	2017	8.0	20.7	21.3	4.0	15.0	24.8
Agriculture	1991	8.0	19.7	15.5	14.7	5.6	42.4
	2017	8.0	10.5	6.5	10.6	1.4	29.9
Self-employment	1991	8.0	22.3	22.7	13.3	3.2	36.9
	2017	8.0	15.1	14.3	6.0	8.3	25.3
Contributing family workers	1991	8.0	3.9	2.9	4.0	0.3	11.0
	2017	8.0	2.8	0.9	4.5	0.2	13.5
Vulnerable employment	1991	8.0	16.6	13.3	11.7	2.2	33.1
	2017	8.0	13.4	13.1	6.8	5.1	24.6
Wage and salaried workers	1991	8.0	77.7	77.4	13.3	63.1	96.8
	2017	8.0	84.9	85.7	6.0	74.7	91.7
Gender employment gap	1991	6.0	13.6	13.3	2.9	9.5	18.3
	2017	6.0	13.9	14.9	3.2	8.0	17.1

Source: authors' calculations.

Along with the rapid deployment of ICT, each country experienced dynamic growth in wealth expressed as per capita income between 1990 and 2017. As Figure 1 shows, all eight CEECs steadily increased their material wealth, with only a slight slowdown in 2008; GDP per capita doubled on average, except for Ukraine. Female labor force participation as a share of the total labor force remained relatively steady (at about 50%) during the study period. However, the gender-disaggregated data indicate that women in CEECs have gradually gained in economic empowerment on average since the post-communist transition began. Women are becoming increasingly involved in tertiary education systems, and young women are becoming less involved in the labor market, and their wages are increasing; meanwhile, female self-employment and vulnerable employment are radically decreasing. Evidence on the reshaping of women's labor role and participation in post-communist economies is also reported in works such as Smith (2000), Lange (2008), Fodor and Glass (2018), Petrović and Radukić (2018), and Avlijaš (2019). Our supposition is supported by the positive trends demonstrated in improvements in female tertiary school enrolment. On average, female tertiary school attendance has grown continuously since 1990 (Fagan et al., 2015; Gallie, 2019; Verick, 2018). Between 1990 and 2017, female tertiary school enrolment rose from 19% to almost 69%. By 2017, three countries—Moldova, Hungary, and Romania—lagged behind (with female tertiary school enrolment at 47% in Moldova and 53% in the other two economies). Not surprisingly, the quickly increasing female tertiary school participation in CEECs has caused a drop in the employment rates for female youth (ages 15–24). Instead of entering the labor market early, young women prefer to continue their education, and this change in attitudes to gaining formal education has direct consequences for the labor market. Between 1991 and 2017, the female youth employment rate fell from 32.5% to 20.7% (see Table 1 and Figure 1). The most radical drops occurred in the Slovak Republic (from 44% to 19%), Romania (from 35% to 17%), and the Czech Republic (from 40% to 23%). In 2017, the lowest female youth employment rates occurred in Moldova (14%) and Bulgaria (16%). However, Moldova had the lowest female youth employment rate even at the beginning of the sample period (16%). Moldova's female youth employment rate grew insignificantly to 19%, and then fell again from 1990 to 2002. Moldova's low female youth employment rate is an effect of a generally poor female engagement in the labor market and other formal economic activities; women remain socially and economically vulnerable and persistent patriarchal attitudes lead to discrimination in social, economic, and political life. They still face many gender-specific barriers preventing access to education and the formal labor market; their job placement opportunities are relatively weak, and they experience segregation into lower-paying occupations with significant wage disparities. Limited access to the financial system constitutes another significant obstacle to setting up their own business and hinders women's engagement in entrepreneurial activities. The broad implementation and growing usage of ICT in Moldova is claimed to be an important "opportunity window" (Pérez, 2003) that may enhance women's engagement by improving the educational opportunities, digital literacy, and other professional skills that facilitate engagement in the activities that a technology-based economy offers.

Given the increasing female tertiary school enrolment, decreasing female youth employment, and fast-growing ICT usage, we may expect to see downward trends in female employment in agriculture, female self-employment, female vulnerable employment, and female contributing family workers and an increase in female wage and salaried workers. The last variable, the gender employment gap, could also be expected to drop; however, this process, as well as the gender pay gap, are complex and conditioned by country-specific legal frameworks (Fodor & Glass, 2018; Perugini & Selezneva, 2015).

As Figure 1 shows, the country-specific trends in $Agric_{y,t}$, $Self_{y,t}$, $Vulner_{y,t}$, and $Family_{y,t}$ support our supposition of a downward trend in all the indicators. Though some paths are unstable and marked by multiple ups and downs, the long-run tendencies show a diminishing share of women engaged in agricultural activities, which is accompanied by decreases in the share of female self-employment, female vulnerable employment, and women working as contributing family workers. Average changes between 1990 and 2017 in $Agric_{y,t}$, $Self_{y,t}$, $Vulner_{y,t}$, and $Family_{y,t}$ are shown in Table 1. The most radical changes are observed in female engagement in agricultural activities and female self-employment (19.7% to 10.5% and 22.3% to 15.1%, respectively). Despite the downward trends in female engagement in agricultural activities, the eight CEECs still differed widely in this regard by 2017. In the Czech and Slovak Republics, female engagement in agricultural activities was 1.6% and 1.4% respectively (it was slightly above 5% and 6% in 1990), while it was still high in Moldova and Romania (30% and 22%, respectively). The share of the economically active population in agricultural activities is determined by the general structure of a nation's economy and its levels of economic and institutional development, as well as non-economic conditions, like natural resources, climate, access to arable land, and geo-physical location. Female self-employment is more diverse, in terms of both the share of self-employment and the general direction of change. In two of the eight countries, the Czech and Slovak Republics, female self-employment increases, but these indicators remained relatively low in 2017 (13% and 10% respectively). On the other hand, Ukraine, Poland, and Romania saw a massive decline in female self-employment (by 22%pp, 11%pp, and 12%pp, respectively). The situation regarding women as contributing family workers differs slightly. We observe huge cross-country disparities; the adjusted Gini indices for 1991 and 2017 are 0.54 and 0.65, which suggests a growing heterogeneity within CEECs in this respect. Since 1990, the share of women working as contributing family workers has been below 1% in the Czech Republic, Slovak Republic, and Ukraine; the share fell from 1.3% to 0.4% by 2017 in Hungary and from 4.4% to 0.8% in Bulgaria. Conversely, the share of women engaged as contributing family workers grew in Romania; it was 5.5% in 1991, peaked in 2000 at 31.3% (sic!), and then fell to 13.5%. As expected, across all eight CEECs, the negative trends in female engagement in the agricultural sector, coinciding with the diminishing female self-employment and female vulnerable employment, are also reflected in a growing share of women classified as wage and salaried workers. On average, the share of women working as wage and salaried workers increased, going from 77.7% in 1991 to almost 85% in 2017. The picture for individual countries is more mixed. In the Czech and Slovak Republics, this value fell by 5%pp and 7%pp, respectively; in the remaining six countries, it rose, with the most massive growth seen in Ukraine (from 63% to 85%). Along with the changes discussed above, we would expect that the gender employment gap fell over time. However, the data collected from the *EU Labor Force Survey 2019* do not fully support this supposition. Data on the gender employment gap are available only for six of the countries[4] in our sample, and the time series trace back only to 2000. However, since 2000, a decline in the gender employment gap is reported only for Bulgaria (-1.5%pp) and the Czech Republic (-1.5%pp); the remaining four countries see increases (the highest in Romania, at +4.7%pp).

The above-discussed changes across CEECs between 1990 and 2017 are accompanied by sectoral structural shifts in their economies. The transition period saw a radically diminishing role of the agricultural sector in gross value added-creation; the role of the industrial sector also diminished in a few countries (see the graphs in the appendix showing country-level changes in agriculture, industry, and services sector value added-creation for 1990 to 2017). Contrariwise, the role of services in value added-creation grew steadily between 1990 and 2017, which demonstrates a reorientation in the CEECs away from industry toward services. The most spectacular

[4] Data for Moldova and Ukraine are not available.

change in sectoral structure is seen in Bulgaria, where the role in value added-creation dropped from 17% to 4% of GDP for the agricultural sector and from 53% to 22% of GDP for the industrial sector, while the role of the services sector grew from 30% to 57% of GDP. Analogous shifts are observable in Moldova, Romania, and Ukraine, where services compensated for drops in the agricultural and industrial sectors. On the aggregate level, the sectoral changes are not massive in the remaining economies, although the *WDI 2019* database reports that total employment in services increased substantially between 1990 and 2017 in countries like Poland, the Slovak Republic, Slovenia, and the Czech Republic even though the share of value added created in that sector remained relatively stable (approximately 50%).

The preliminary evidence for CEECs clearly shows that, from 1990 to 2017, a rapid diffusion of ICT and dynamic growth of per capita income were accompanied by increased female participation in tertiary education and falling youth female labor market participation. These positive changes demonstrate a stable socioeconomic development in the examined countries, which is also visible through the decreasing female participation in agricultural activities and the radical decline in female self-employment and vulnerable employment. Increased female wage and salaried employment is clearly detectable.

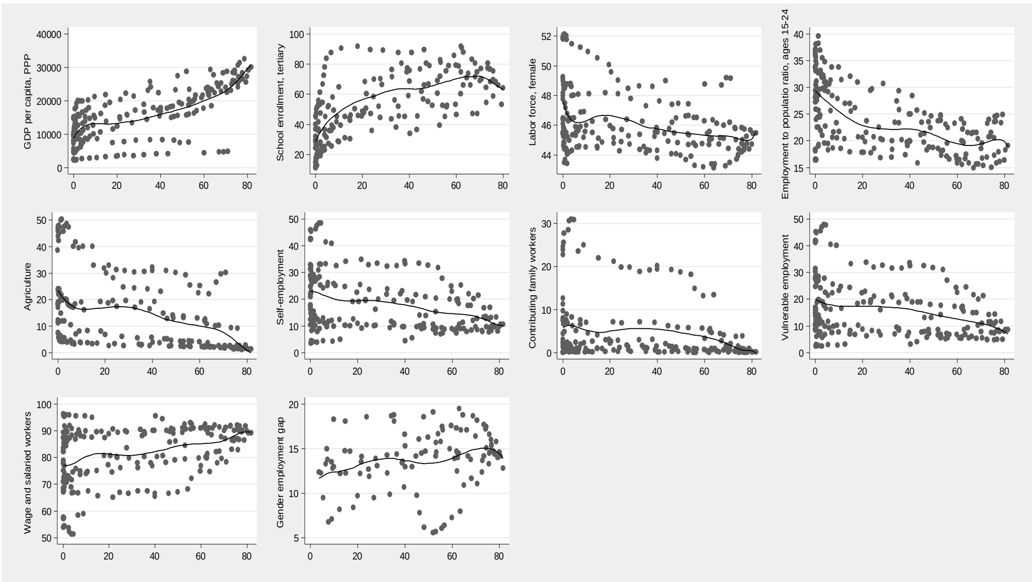
Panel regression estimates

In the second step, we investigate if growing ICT deployment influences female economic activity. We also examine the main variables in terms of GDP per capita to verify if ICT`s impact on female economic activity is manifested indirectly through the economic growth channel. We start by examining the statistical correlations between ICT and GDP per capita and the other variables. Next, we use PVAR models to capture the potential causality between growing ICT usage and female economic activity.

Figures 2 and 3 graphically display the examined relationships. When correlating IU with other variables, we expect that growing Internet usage is positively correlated with economic growth, the share of women wage and salaried workers, and the rate of female tertiary school enrolment, whereas we expect IU to have negative associations with the remaining variables. We expect to see analogous statistical relationships when examining GDP per capita in terms of the other variables. Tables 2 and 3 summarize the PVAR estimates, which reveal temporal and spatial causality between the variables. Bearing in mind the nature of the selected variables and the interdependencies among the national economies, we hypothesize that lagged variables in country y_1 may impact changes in other domestic variables in country y_2. We hypothesise that a positive impact of ICT and overall technological change on female economic activity may also be indirectly demonstrated through growth in national output and increases in the share of women working as wage and salaried workers. Hence, we also examine the relationships between economic growth and a bundle of female-related variables.

Figures 2 and 3 graph the relationships between consecutive pairs of variables. A first glance reveals relatively poor regularities and weak interdependencies between the examined variables, although the statistical relationships seem to have the expected signs. A strongly positive statistical relationship is identified between GDP per capita and IU ($r^2 = 0.69$) and between female tertiary school enrolment and IU ($r^2 = 0.66$). A positive but much weaker relationship is seen between Internet users and $Wage_{y,t}$. We might also expect that growing ICT penetration, dynamic economic growth, and increasing female economic activity would also enhance the decline in the gender employment gap; hence, $IU_{y,t}$ and $Gender_{y,t}$ should have negative relationships. However, the graphical evidence suggests rather weak associations between the variables, although the correlation coefficients are positive (0.18). As for the remaining female-related indicators, the graphs in Figure 2 display negative associations between growing Internet penetration rates and the variables. This may suggest that increasing ICT deployment is accompanied by falling youth female employment but also by increased female engagement in agricultural activities, female self-employment, the share of women in the vulnerable and/or contributing family workers category, and the share of women in the labor force. The strongest relationships are those for $IU_{y,t}$ versus $Agric_{y,t}$ and $IU_{y,t}$ versus $Empl15\text{-}24_{y,t}$.

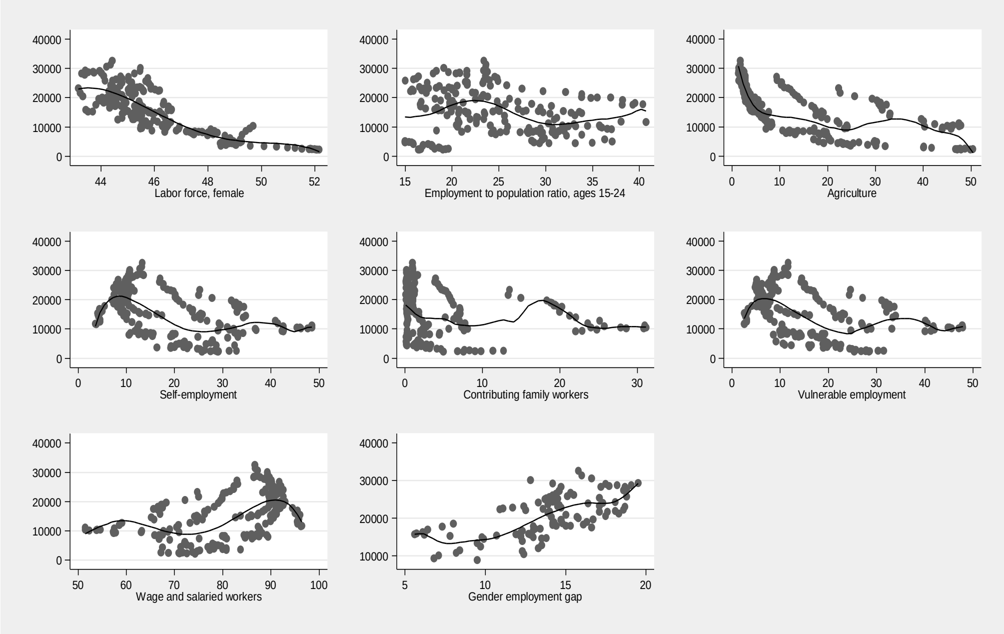
Figure 2. Internet users versus selected variables, 1990–2017



Source: Authors' elaboration.
Note: X-axis = Internet Users (%); panel strongly balanced; kernel-weighted local polynomial smoothing applied; degree of polynomial = adjusted; raw data used.

Similar results are observed for the relationships between economic growth and the remaining indicators (see Figure 3). As expected, per capita income is strongly negatively associated with the female labor force, female engagement in the agricultural sector, and female vulnerable/self-employment.

Figure 3. GDP per capita versus selected variable. Period 1990-2017.



Source: Authors' elaboration.
Note: Y-axis = GDP per capita, PPP (in USD); panel strongly balanced; kernel-weighted local polynomial smoothing applied; degree of polynomial = adjusted; raw data used.

We also detect a relatively strong positive relationship between GDP per capita and the gender employment gap (r2 = 0.69), which conflicts with our supposition that economic advances gradually eliminate gender disparities. Paradoxically, economic growth does not reduce gender employment disparities across the eight CEECs; instead, we observe growing inequalities. The gender employment gap measures the difference in employment rates between men and women aged 20 to 64. According to *EU Labor Force Survey* data, this gap was relatively large between 2000 and 2017, especially in the Czech and Slovak Republics (an average of 18%pp and 15%pp respectively). In 2017, the average gender employment gap for all European Union countries was 11.6%pp, and 11.2%pp in Eurozone countries.

Tables 2 and 3 summarize the results of the estimated PVAR regression models and Granger causality Wald tests. Each model considers $IU_{y,t}$ as a potential determinant of economic growth, as well as the other female-related variables. We expect to see temporal and spatial causality between the variables examined. We add two variables in each equation to control for structural changes in the industrial sector ($Ind_{y,t}$) and services sector ($Serv_{y,t}$).

The results generated by the PVAR models may be interpreted as the average responses of the endogenous variables to changes in any variable after time-invariant characteristics are controlled for. Prior to estimating the models, we analyze the models' lag order using modified Akaike information criteria, modified Bayesian information criteria, and modified Hannan–Quinn information criteria. The results unequivocally suggest using one- or two-year-lag panel vector autoregression models.

Table 2. Panel VAR estimates (I), 1990–2017

	$\gamma_{y,t} = GDP$	$\gamma_{y,t} = GDP$	$\gamma_{y,t} = GDP$	$\gamma_{y,t} = Agric$	$\gamma_{y,t} = Agric$	$\gamma_{y,t} = Agric$ e	$\gamma_{y,t} = Family$	$\gamma_{y,t} = Family$	$\gamma_{y,t} = Family$	$\gamma_{y,t} = Vulner$	$\gamma_{y,t} = Vulner$	$\gamma_{y,t} = Vulner$	$\gamma_{y,t} = Self$	$\gamma_{y,t} = Self$	$\gamma_{y,t} = Self$
GDP (t-1)	**1.39 [0.14]**	**0.91 [0.03]**	**0.93 [0.04]**												
GDP (t-2)	**-0.39 [0.11]**														
Agric (t-1)				**0.78 [0.14]**	**0.91 [0.06]**	**0.90 [0.05]**									
Agric (t-2)				0.09 [0.07]											
Family (t-1)							**0.81 [0.08]**	0.62 [1.04]	**0.85 [0.07]**						
Vulner (t-1)										**0.69 [0.30]**	**0.97 [0.04]**	**0.95 [0.13]**			
Self (t-1)													0.48 [0.68]	**0.94 [0.06]**	**0.91 [0.12]**
Self (t-2)													0.16 [0.12]		
IU (t-1)	-0.01 [0.57]	**0.014 [0.0]**	0.00 [0.01]	-0.01 [0.04]	-0.01 [0.02]	-0.01 [0.1]	-0.03 [0.02]	-1.07 [0.38]	-0.01 [0.05]	-0.01 [0.01]	0.00 [0.02]	0.00 [0.02]	-0.12 [0.22]	0.00 [0.01]	0.00 [0.01]
IU (t-2)	**0.02 [0.00]**			-0.00 [0.03]									0.09 [0.16]		
Ind (t-1)		0.07 [0.07]			0.04 [0.72]			-3.17 [13.6]			0.15 [0.83]			0.28 [0.63]	
Serv (t-)			0.29 [0.44]			0.00 [0.36]			-0.41 [1.47]			-0.17 [0.73]			-0.29 [0.57]
#obs.	176	174	174	177	174	174	185	174	174	185	174	174	177	174	174
	$\gamma_{y,t} = IU$	$\gamma_{y,t} = Ind$	$\gamma_{y,t} = Serv$ e	$\gamma_{y,t} = IU$	$\gamma_{y,t} = Ind$	$\gamma_{y,t} = Serv$	$\gamma_{y,t} = IU$	$\gamma_{y,t} = Ind$	$\gamma_{y,t} = Serv$	$\gamma_{y,t} = IU$	$\gamma_{y,t} = Ind$	$\gamma_{y,t} = Serv$	$\gamma_{y,t} = IU$	$\gamma_{y,t} = Ind$	$\gamma_{y,t} = Serv$
GDP (t-1)	0.02 [0.57]	-0.05 [0.05]	-0.01 [0.05]												
GDP (t-2)	0.05 [0.45]														
gric (t-1)				-0.02 [0.18]	0.02 [0.03]	0.00 [0.04]									
gric (t-2)				0.05 [0.18]											
amily (t-1)							-0.11 [0.09]	0.26 [0.82]	0.00 [0.02]						

Vulner (t-1)										-0.95 [0.77]	0.00 [0.03]	-0.01 [0.07]			
Self (t-1)													0.07 [1.6]	0.03 [0.04]	-0.01 [0.08]
Self (t-2)													0.24 [0.32]		
IU (t-1)	**0.97 [0.08]**	0.06 [0.01]	0.00 [0.02]	**1.03 [0.10]**	0.01 [0.01]	-0.001 [0.01]	**0.81 [0.03]**	0.09 [0.31]	0.00 [0.00]	**0.81 [0.04]**	-0.01 [0.01]	0.00 [0.00]	**1.13 [0.57]**	-0.01 [0.00]	0.01 [0.00]
IU (t-2)	-0.10 [0.07]			-0.13 [0.08]									-0.21 [0.14]		
Ind (t-1)		**0.81 [0.14]**			0.71 [0.55]			4.18 [10.8]			0.28 [0.52]			0.35 [0.46]	
Serv (t-)			0.65 [0.53]			0.81 [0.25]			0.75 [0.24]			**0.81 [0.38]**			**0.81 [0.36]**
Granger causality Wald test - χ^2 [Prob > χ^2]															
GDP/Agric/Family/Vulner/Self equation	**6.21 [0.04]**			5.39 [0.05]			2.91 [0.08]			1.32 [0.25]			0.42 [0.82]		
IU equation	0.36 [0.88]			0.12 [0.94]			1.48 [0.22]			1.51 [0.22]			1.01 [0.61]		
Ind equation		1.39 [0.49]			1.82 [0.41]			0.10 [0.95]			1.14 [0.56]			1.16 [0.56]	
Serv equation			0.17 [0.95]			0.06 [0.96]			0.25 [0.87]			0.05 [0.97]			1.25 [0.58]

Source: Authors' calculations.

Note: GMM estimator applied; Number of lags based on AIC, BIC, and HQIC criteria; first or second lags of the explanatory variables used as instruments; SE below coefficients; model validation parameters and checks available on request; coefficients in **bold** are **statistically significant at 5% level**; GMM weight matrix robust; all values are logged.

Table 3. Panel VAR estimates (II), 1990–2017

	$\gamma_{y,t} = Wage$	$\gamma_{y,t} = Wage$	$\gamma_{y,t} = Wage$	$\gamma_{y,t} = Empl15-24$	$\gamma_{y,t} = Empl15-24$	$\gamma_{y,t} = Empl15-24$	$\gamma_{y,t} = Labor$	$\gamma_{y,t} = Labor$	$\gamma_{y,t} = Labor$	$\gamma_{y,t} = Gender$	$\gamma_{y,t} = Gender$	$\gamma_{y,t} = Gender$	$\gamma_{y,t} = School$	$\gamma_{y,t} = School$	$\gamma_{y,t} = School$
Wage (t-1)	**0.73 [0.17]**	**0.92 [0.12]**	1.48 [3.5]												
Empl15-24 (t-1)				**0.72 [0.10]**	0.38 [0.46]	**0.85 [0.08]**									
Labor (t-1)							0.14 [0.83]	3.36 [8.7]	0.39 [0.45]						
Gender (t-1)										0.79 [0.54]	**1.44 [0.73]**	-12.2 [198.3]			
School (t-1)													2.75 [2.04]	**0.95 [0.15]**	-1.02 [7.01]
School (t-2)													-1.3 [1.3]		
IU (t-1)	0.005 [0.00]	0.00 [0.00]	-0.03 [0.23]	**-0.01 [0.00]**	-0.06 [0.05]	0.02 [0.01]	-0.00 [0.00]	0.01 [0.05]	0.00 [0.00]	0.00 [0.01]	0.00 [0.01]	0.85 [12.4]	0.04 [0.08]	-0.04 [0.05]	0.81 [2.93]
IU (t-2)													-0.09 [0.15]		
Ind (t-1)		-0.07 [0.06]			-1.3 [1.3]			0.14 [0.45]			-0.81 [1.8]			-2.4 [1.9]	
Serv (t-)			0.94 [5.92]			**-1.06 [0.52]**			-0.07 [0.05]			-35.1 [514.2]			-16.3 [59.1]
#obs.	185	174	174	185	174	174	185	174	174	96	96	96	156	155	155
	$\gamma_{y,t} = IU$	$\gamma_{y,t} = Ind$	$\gamma_{y,t} = Serv$	$\gamma_{y,t} = IU$	$\gamma_{y,t} = Ind$	$\gamma_{y,t} = Serv$	$\gamma_{y,t} = IU$	$\gamma_{y,t} = Ind$	$\gamma_{y,t} = Serv$	$\gamma_{y,t} = IU$	$\gamma_{y,t} = Ind$	$\gamma_{y,t} = Serv$	$\gamma_{y,t} = IU$	$\gamma_{y,t} = Ind$	$\gamma_{y,t} = Serv$
Wage (t-1)	2.14 [1.48]	-0.40 [0.35]	2.96 [18.4]												
Empl15-24 (t-1)				-0.55 [0.39]	0.18 [0.24]	0.02 [0.05]									
Labor (t-1)							-33.1 [36.9]	-25.8 [86.6]	0.81 [3.6]						
Gender (t-1)										0.08	0.00 [0.28]	-0.67 [10.1]			
School (t-1)										[0.77]			0.81 [2.3]	0.00 [0.04]	0.07 [0.49]
School (t-2)										0.08			-0.33 [1.5]		
(t-1)	**0.81 [0.03]**	0.00 [0.00]	-0.17 [1.2]	**0.51 [0.03]**	0.01 [0.02]	0.00 [0.00]	**0.71 [0.13]**	-0.14 [0.48]	0.00 [0.00]	[0.77]	-0.01 [0.00]	0.04 [0.63]	**0.95 [0.09**	-0.01 [0.01]	-0.02 [0.21]
(t-2)													-0.15 [0.16]		
(t-1)		**0.77 [0.17]**			1.16 [0.63]			-0.44 [4.4]			1.19 [0.69]			0.32 [0.63]	

Serv (t-)			5.29 [30.5]			**0.65 [0.32]**			0.76 [0.42]			-0.71 [26.0]			1.37 [4.16]
			Granger causality Wald test - χ^2 [Prob > χ^2]												
Wage/Empl 15-24/Labor/Gender/School equation	3.5 [0.06]			4.34 [0.03]			0.98 [0.32]			0.08 [0.77]			0.45 [0.79]		
IU equation	2.15 [0.14]			2.02 [0.15]			0.81 [0.37]			0.05 [0.81]			3.4 [0.18]		
Ind equation		1.47 [0.49]			0.84 [0.65]			0.11 [0.94]			2.43 [0.29]			0.58 [0.74]	
Serv equation			0.08 [0.96]			1.28 [0.56]			1.52 [0.46]			0.03 [0.98]			0.31 [0.85]

Source: Authors' calculations. Note: Number of lags based on AIC, BIC, and HQIC criteria; first or second lags of the explanatory variables used as instruments; SE below coefficients; model validation parameters and checks available on request; coefficients in **bold** are **statistically significant at 5% level**; GMM weight matrix robust; all values are logged.

Our results are mixed, and the coefficients do not unequivocally support our hypothesis of causal links between ICT deployment, economic growth, and female economic activity. We can draw a valid conclusion only from the statistical significance of the lagged value of a given variable, showing that its over-time changes are impacted by its past values. In the IU equations, we observe that growth in Internet penetration rates is conditioned by $IU_{y,t}$ observed in past periods, which may support the hypothesis that strong network effects (Katz & Shapiro, 1994) are driving ICT diffusion. In most cases, the coefficients of the other variables seem to have random values, and very few of the variables appear to be statistically significant; hence, no regularities may be conclusively identified.

Table 2 reports the estimates of system equations on causality between ICT and $GDP_{y,t,}$ $Agric_{y,t}$, $Family_{y,t}$, $Vulner_{y,t}$, $Self_{y,t}$, and the additional control variables $Ind_{y,t}$ and $Serv_{y,t}$. The results indicate that changes in $IU_{y,t}$ do not predict changes in any of the variables listed above, except for $GDP_{y,t}$. In other words, given the PVAR regression estimates, we may not conclude that shifts in Internet usage predict changes in the proportion of women working in agriculture, serving as family workers, or being self-employed. Nor do we find statistically significant estimates regarding vulnerable employment. Moreover, neither $Ind_{y,t}$ nor $Serv_{y,t}$ are statistically significant regarding changes in $GDP_{y,t,}$ $Agric_{y,t}$, $Family_{y,t}$, $Vulner_{y,t}$, or $Self_{y,t}$. Thus, as with Internet use, we cannot claim that changes in $IU_{y,t}$ predict changes in $GDP_{y,t,}$ $Agric_{y,t}$, $Family_{y,t}$, $Vulner_{y,t}$, or $Self_{y,t}$.

The Granger causality tests support these findings, by indicating a lack of causality. The results of the Wald tests, summarized at the bottom of Table 2, show that the null hypothesis may not be rejected; hence, $IU_{y,t}$ cannot be used to predict changes in $Agric_{y,t}$, $Family_{y,t}$, $Vulner_{y,t}$, or $Self_{y,t}$. However, the estimated parameters for the system of equations, $\gamma_{y,t} = GDP \leftrightarrow \gamma_{y,t} = IU$, show that the two-year-lagged values of Internet penetration rates ($IU_{y,t}$) have positive and statistically significant (though relatively weak [estimated parameter = 0.02]) impacts on economic growth across the eight countries from 1990 to 2017. The results of the Granger causality tests support these findings. They may support our supposition that a large majority of the positive effects due to technological progress are ultimately "accumulated" in economic growth, which may thus be the most reliable channel by which to detect causality. However, if reverse causality is considered, our findings do not allow us to conclude that growth in Internet penetration rates is enhanced by economic growth. In this case, as in all other PVAR specifications, we find only the existence of a path-depended development of $IU_{y,t}$, as the estimated parameters of the IU one-year-lag variable are all positive and statistically significant.

Similar conclusions can be derived from the PVAR estimates shown in Table 3, where we control for $Wage_{y,t}$, $Empl15\text{-}24_{y,t}$, $Labor_{y,t}$, $Gender_{y,t}$, and $School_{y,t}$ as well as additional control variables $Ind_{y,t}$ and $Serv_{y,t}$ to trace the potential causality between them and $IU_{y,t}$. The estimates are similar to those reported in Table 2. The coefficients do not support the hypothesis that changes in the share of women in wage and salaried work, the share of women in the labor force, the gender employment gap, or female tertiary school enrolment can be predicted by changes in $IU_{y,t}$. This is supported by the Wald test results, which indicate no causality between consecutive pairs of variables. Additionally, due to the simultaneous estimation of the $IU_{y,t}$ equations, we gain insight into the reverse relationships and hence the potential determinants of ICT diffusion in the eight countries. Again, no reverse causality is detected. Hence, these estimates do not allow us to conclude that certain economic changes foster growth in ICT access and use. Table 3 summarizes the results of the estimates of system equations, $\gamma_{y,t} = \mathrm{Empl15} - 24 \leftrightarrow \gamma_{y,t} = \mathrm{IU}$. In contrast to the other PVAR specifications, the reported coefficients support our hypothesis that technological progress and economic reorientation toward technology-based production are associated with gradual decreases in female youth employment, which may in turn be a direct consequence of the rapidly increasing female participation in tertiary education. The estimated coefficient of the IU one-year-lag variable is negative and statistically significant, as expected. The Granger causality test result indicates the existence of causality between changes in $IU_{y,t}$ and Empl15-$14_{y,t}$. As in previous cases, we find no causal relationships between $Ind_{y,t}$ and $Wage_{y,t}$, Empl15-$24_{y,t}$, $Labor_{y,t}$, $Gender_{y,t}$, or $School_{y,t}$, which suggests that changes in $Ind_{y,t}$ may not predict changes in any of the variables listed above. Regarding $Serv_{y,t}$, the second control variable introduced in our analysis, it is statistically significant only for Empl15-$24_{y,t}$, where the estimated parameter is (-1.06). This would suggest that the declining role of the services sector in CEECs is driving the shifts in Empl15-$24_{y,t}$, which conflicts with the general trend observed in the sample economies.

Unfortunately, neither this case nor previous cases (see able 3) display any kind of reverse causality, such as shifts and/or improvements in female school enrolment fostering increasing and broader Internet use throughout economies and societies.

Though highly mixed, these results do support the hypothesis that ICT, economic growth, and female-related changes are interrelated. It can be argued that ICT deployment fosters growth in per capita income and reduced female youth employment. We consider that the major factor in the latter is the growing female participation in tertiary education. These results may (indirectly) support our hypothesis on the causality between growth in ICT deployment, economic growth, school enrolment, and female economic activity. There is undoubtedly a kind of synergy; the relationships are all bidirectional, and we observe a reverse causal loop. Moreover, we have uncovered strong network effects that drive ICT deployment both within and across countries. In each estimated PVAR regression, we observe statistically significant and positive coefficients of the IU one-year-lag variables, supporting our hypothesis that the ICT process is highly endogenous.

6. Conclusions

This study has examined, from a macro perspective, the association between ICT deployment in an economy, women's engagement in labor markets, and economic growth in eight CEECs from 1990 to 2017. Our major research goal was to contribute to the literature in three main ways: by tracing the changes in women's engagement in labor market across CEECs countries; examining the statistical relationships between growing ICT use and changes in women's labor market engagement; and verifying our hypothesis regarding the impact of growing ICT use on women's labor market engagement in the sample countries. The preliminary analysis has shown that, during the sample period's 28 years, the countries underwent substantial changes in material economic welfare (their GDP per capita almost doubled) and in Internet penetration rates, which went from practically nil in 1990 to an average of 73% in 2017. In addition, most of the countries experienced drastic declines in the share of women in agricultural work, female youth employment, and the share of women serving as contributing family workers. At the same time, we observe upward trends in girls' tertiary school enrolment and women's wage and salaried work.

We have also investigated the interdependencies among the variables by estimating PVAR models. Unfortunately, no robust conclusions can be drawn from the estimates, the coefficients appearing to be fairly random with no regularities emerging. Moreover, Wald tests of Granger causality suggest that changes in ICT deployment cannot predict changes in the proxies for women's economic activity. However, we have traced such linkages between ICT and economic growth and between ICT and female youth employment. The potential linkages between technological advances (as approximated by Internet penetration rates), economic growth, and female-related indicators constitute two-way relationships. The statistical linkages between ICT deployment and the variables representing women's engagement in economic activity are clearly bidirectional, but these interdependencies cannot be encapsulated in one single equation. Our results should thus be interpreted carefully, since the statistical relationships we have reported may be spurious. Of course, our intention was not to show that the diffusion and deployment of ICTs is the sole factor driving social and economic changes in the sample CEECs. Obviously, such changes are slow and are sometimes hard to identify or trace in the short run.

Nevertheless, our preliminary inquiry can pave the way for future research, which could concentrate on unveiling the country-specific conditions that enable or hinder greater female access to labor markets and engagement in value added-creation. Country-specific analyses are necessary because economic and political transitions and post-transition development patterns are heterogeneous in the sample CEECs. Studying these country-wide conditions would be of interest to scholars and policymakers. More profound and detailed research on the country-specific barriers to female engagement in labor markets and different forms of formal economic activities would offer deeper insights. Furthermore, a more solid understanding is required of the specificity of the jobs (including ICT-based work) executed by women since (as mentioned) female workers tend to perform more tasks that are routine and require little analytical effort. Studying the evolution of routine work might offer interesting insights into how to proxy for female labor participation patterns.

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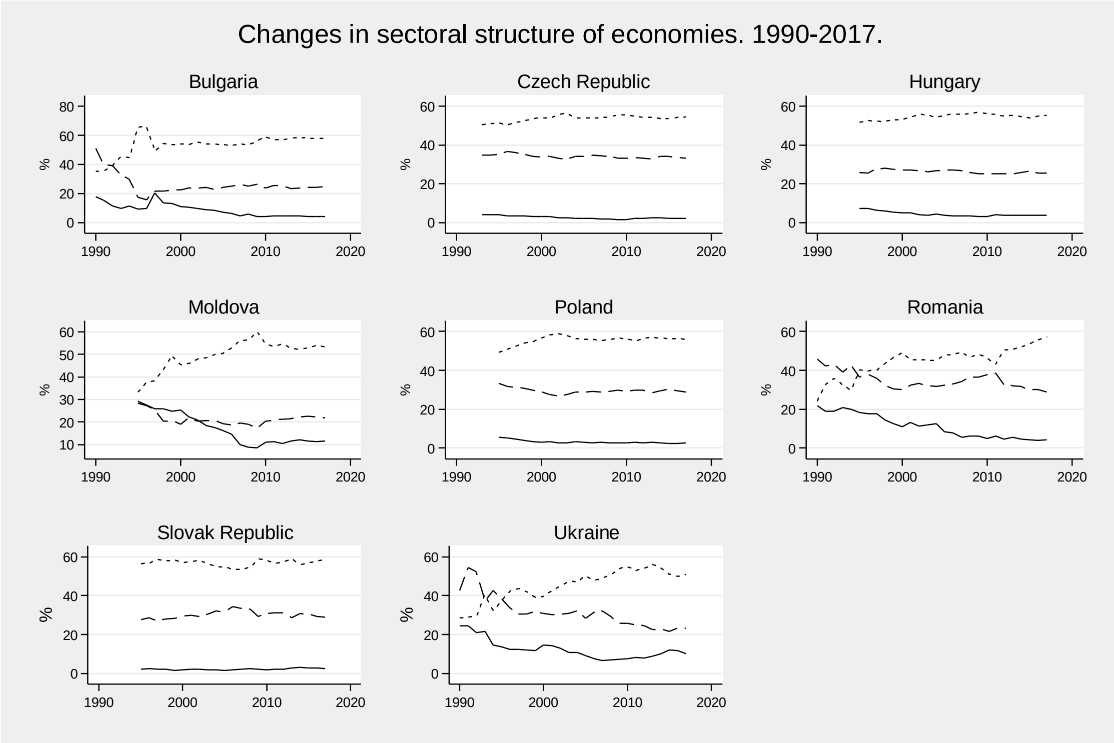
Appendix



Source: Authors' elaboration.

Note: solid line = agriculture; dashed line = industry; short-dashed line = services; Y-axis = share of agriculture/industry/services sector in value added (as share of GDP).