

DOES INNOVATION MEDIATE THE EFFECT OF DIGITAL CONNECTIVITY ON EMPLOYMENT? EVIDENCE FROM EUROPEAN UNION COUNTRIES

NÎTESCU ELENA IULIA

ASST. PHD., „CONSTANTIN BRÂNCUȘI” UNIVERSITY, TÂRGU-JIU, ROMANIA

e-mail: iuliagrigorie99@gmail.com

Abstract

Digital connectivity is recognized as an important factor for the development of the labour market, but the mechanisms by which it influences employment remain insufficiently explained in the literature. This study investigates the role of innovation as a mediation mechanism in the relationship between internet access and employment in the Member States of the European Union. The analysis is based on data from 2013–2023 and uses a structural equation model estimated by the maximum likelihood method. The results highlight a direct and positive effect of internet access on employment, as well as a significant effect on innovation performance, which in turn positively influences employment. In contrast, while digital infrastructure contributes to the development of the ICT sector, it does not mediate the relationship between digitalization and employment. The conclusions suggest that the benefits of digital connectivity on the labour market are generated mainly by stimulating innovation, rather than by expanding the activity of the ICT sector, providing relevant arguments for underpinning European policies on digital transformation, innovation and employment.

Keywords: internet access, innovation, employment, mediation analysis, modeling structural equations, European Union

JEL Classification: O33, J21, O31

1. Introduction

Digital transformation has emerged as one of the main priorities of European economic policies over the past decade. However, this relationship is more complex than the political discourse suggests. Although numerous studies have demonstrated the existence of a positive link between digitalization and macroeconomic performance, including in European Union Member States, where Mura and Donath (2023) highlight a positive and robust impact of digitalization on economic growth over a twenty-two-year period, the mechanisms by which digital connectivity influences labour market outcomes are still poorly understood. In other words, we know that digitalization contributes to improving economic performance, but we know much less about how these effects are transmitted to employment.

The literature on the impact of internet access on employment has developed considerably in recent years. Atasoy (2013), analyzing the expansion of broadband infrastructure in the United States between 1999 and 2007, shows that internet access is associated with an increase in the employment rate, with the effects being more pronounced in rural and remote regions. Similarly, Hjort and Poulsen (2019) demonstrate that the introduction of submarine cables in African states has had a significant positive impact on employment, including among people with low levels of education. The authors explain these results by the emergence of new firms, increased productivity and expansion of exports. At European level, Stockinger (2019) confirms the favorable effects of infrastructure availability on employment, but highlights that the benefits are stronger when infrastructure is actually used and not just available. The same conclusion is supported by Bertschek et al. (2015), who show that the aggregate impact of broadband internet on the labour market is positive, but differs depending on the level of qualification of the workforce and the specificities of economic sectors, with the greatest benefits being observed in the service sector and among highly skilled workers.

The difference between the existence of digital infrastructure and its actual use is also supported by the literature on the digital divide. Van Deursen and van Dijk (2014) show that as internet access becomes almost universal, differences between individuals are no longer

mainly generated by a lack of connectivity, but by digital skills and the way in which technology is used, a phenomenon described as the second-level digital divide. In a subsequent work, the same authors (van Deursen and van Dijk, 2019) highlight the fact that the first-level gap does not disappear completely, but turns into an inequality in access to material resources necessary for the use of technology. From the perspective of macroeconomic analysis, this distinction is essential, as broadband coverage and effective internet access reflect different dimensions of digitalization and can influence economic performance through distinct mechanisms.

A complementary direction of the literature looks at the relationship between innovation and employment. According to Schumpeter (1942), technological progress leads simultaneously to the disappearance of some economic activities and the emergence of new ones, so that the final effect on employment cannot be anticipated. Developing this perspective, the theory of Vivarelli (2015) identifies the main mechanisms by which the initial labor substitution effects generated by process innovation can be compensated, namely through new investments, cost and price reduction, development of new products and demand expansion. However, the author points out that these mechanisms do not work automatically or with the same intensity in all economies. Empirical evidence indicates that product innovation generally has a positive effect on employment, while process innovation tends to reduce labor demand (Vivarelli, Evangelista, & Pianta, 1996). Recent analyses (Montobbio et al., 2024; Prytkova et al., 2024) confirm that the aggregate effect of innovation on employment remains positive, but it depends on the structure of the innovation process and the institutional characteristics of the economy. In the case of the European Union, Evangelista, Guerrieri and Meliciani (2014) show that digital technologies contribute to improving economic performance, but the magnitude of these effects is conditioned by the ability of national economies to absorb and capitalize on innovation.

This study addresses this gap through a mediation analysis applied to the Member States of the European Union. The contribution of the study is threefold. First of all, the article integrates two literatures treated so far separately, proposing and empirically testing innovation as an explanatory mechanism of the relationship between connectivity and employment. Secondly, by disaggregating the digital infrastructure into effective access and potential coverage, the study translates the theoretical distinction between the levels of the digital divide to the macroeconomic level, providing evidence of the fact that the two dimensions operate through different channels. Third, by including the ICT sector as an alternative mediator, the article explicitly tests an assumption frequently invoked in public policy documents, but rarely rigorously tested, that the expansion of the digital sector is, in itself, a channel for job creation.

2. Literature review

The analysis of the impact of digital financial instruments on household decision-making is based on an interdisciplinary theoretical framework and allows a complex understanding of the mechanisms by which the digitization of financial services transforms the processes of choice and allocation of resources at individual and family level.

The relationship between digital infrastructure and employment has been approached in the empirical literature through three complementary methodological perspectives: macroeconomic analyses by country panel, experimental studies exploiting exogenous variations in network deployment, and firm-level analyses.

At the macroeconomic level, Czernich et al. (2011) estimate an increase in broadband penetration increases the annual growth of GDP per capita, using a model with instrumental variables derived from a logistic model. Although the dependent variable is economic growth

and not employment, the result establishes the macroeconomic premise of the present analysis: digital infrastructure functions as a general-purpose technology, with effects that propagate across the economy.

The record on the actual employment is more recent and methodologically more robust. Atasoy (2013) identifies, through fixed-effect models, an increase in the employment rate associated with the acquisition of broadband access, with most of the gains coming from the expansion of the labor demand of existing firms and the growth of the active population. Hjort and Poulsen (2019), exploiting the gradual arrival of submarine cables on the African coast, report substantial positive effects on employment rates in twelve countries, supported by the entry of new firms, increased productivity and export expansion. Stockinger (2019) confirms the result on German data at local unit level. The synthesis by Bertschek et al. (2015) converges towards the conclusion of a positive but heterogeneous aggregate effect focused on highly skilled workers and firms in the service sector.

An essential aspect, insufficiently capitalized on in macroeconomic analyses, is the distinction between the availability and adoption of infrastructure. Stockinger (2019) notes that empirical studies systematically identify stronger and more robust effects for the actual adoption of broadband than for its mere availability. This empirical finding has a theoretical counterpart in the literature on the digital divide: van Deursen and van Dijk (2014) demonstrate that, as physical access approaches saturation, inequalities shift towards skills and types of use, and their subsequent contribution shows that the first-level gap does not disappear either, but turns into inequality of material access (van Deursen and van Dijk, 2019).

Thus, the following research hypotheses are drawn:

H1. Innovation performance mediates the relationship between internet access and occupancy rates.

H2. Innovation performance mediates the relationship between broadband coverage and occupancy rate.

H3. The ICT sector's contribution to GDP mediates the relationship between internet access and employment rates.

H4. The ICT sector's contribution to GDP mediates the relationship between broadband coverage and employment.

3. Data and Methodology

The analysis is based on a balanced panel comprising the 27 Member States of the European Union, observed annually in the period 2013-2023, resulting in a total of 297 country-year observations. The timeframe was selected on the basis of two criteria: consistent availability of high-speed broadband coverage indicators in Eurostat databases since 2013 and coverage of a full business cycle, including the post-crisis recovery, the pandemic shock of 2020-2021 and the subsequent normalization period.

The composition of the sample requires two clarifications. First, Croatia joined the European Union in July 2013 and the United Kingdom left it in January 2020; the sample is defined by the current composition of the Union (EU-27), with the United Kingdom excluded for the entire period to ensure consistency of the unit of analysis. Secondly, the data for Croatia in 2013 are available for all Eurostat indicators used, so the panel remains balanced.

Table No. 1. Variables used in the analysis

Variable	Abbrev.	Operational Definition	Unit	Source
Employment rate	EMP	Employment rate of the population aged 20-64 years	%	Eurostat
Internet access	IAC	Share of households with internet access at home	%	Eurostat
Broadband coverage	BBC	Share of households covered by Next Generation Access (NGA) broadband networks	%	Eurostat

Innovation performance	GII	Aggregate score of the Global Innovation Index	0-100	WIPO
ICT sector	ICT	Value added of the ICT sector as a share of GDP	%	Eurostat

Source: Author contribution

Table No. 2 presents the descriptive statistics for the model variables, calculated on the full panel of 297 country-year observations corresponding to the 27 Member States observed over eleven years.

Table No. 2. Summary statistics of variables used in the econometric analysis, 2007-2023

	POV	EMP	IAC	ICT	BBC	GII
Valid	291	291	295	182	297	294
Missing	6	6	2	115	0	3
Mean	22.411	72.413	85.381	4.442	49.044	48.547
Std. Deviation	6.436	6.099	9.340	1.279	29.814	7.421
Minimum	10.800	52.900	53.710	1.990	0.000	34.700
Maximum	41.900	83.500	99.180	10.140	100.000	64.200

Source: Author contribution in JASP19

The BBC variable records the largest dispersion of the set, with a standard deviation of 29.81 percentage points and a range that covers virtually the entire possible scale. The average of 49.04% indicates that, over the entire period analyzed, around half of European households benefited from coverage through next-generation networks. This dispersion simultaneously reflects the structural heterogeneity between Member States and the strong dynamics of network deployment between 2013 and 2023.

By contrast, households' access to the internet has a high average (85.38%) and a moderate dispersion (9.34), patterns characteristic of an indicator close to saturation. The maximum value of 99.18% indicates the practical achievement of universality in states with advanced connectivity, while the minimum of 53.71% corresponds to the first observations of the states lagging behind.

The mediation analysis applied in the research is estimated by the maximum likelihood (ML) method, using the SEM package from the JASP program. The choice of simultaneous estimation of the whole system, rather than sequential estimation by separate regressions, is justified by the ability of SEM to incorporate correlations between residues and to provide global model suitability tests.

Indirect effects testing is done using the bootstrap method with 5,000 replications and bias-corrected percentile confidence intervals. This choice replaces the standard errors obtained by the delta method, which assume the normality of the distribution of the product of the coefficients, an assumption systematically violated in practice, since the product of two normal variables is not itself normally distributed (Preacher and Hayes, 2008). The bootstrap method does not impose this restriction and provides superior accuracy in moderate-sized samples.

4. Results and discussions

The first dimension of the analysis concerns the Pearson correlations in the form of a heat map during the period 2013-2023, illustrated in Figure No. 1.

The bivariate associations with the dependent variable are all positive and statistically significant. The employment rate correlates most strongly with broadband coverage ($r = 0.503$; $p < 0.001$), followed by internet access ($r = 0.446$; $p < 0.001$), ICT contribution ($r = 0.294$; $p < 0.001$) and innovation performance ($r = 0.247$; $p < 0.001$).

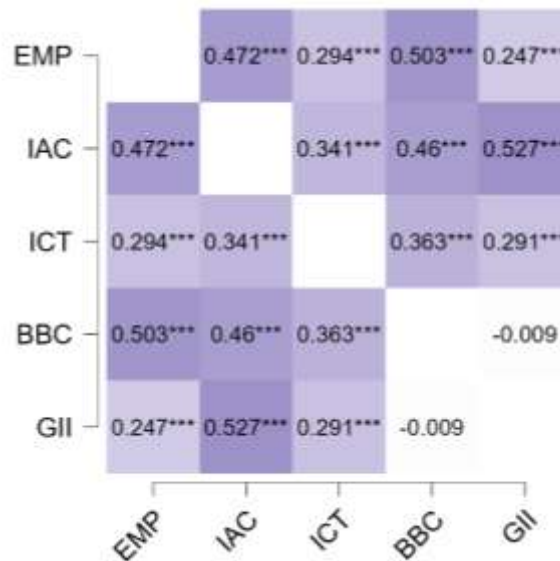


Figure No. 1. Pearson's heatmap, EU-27, 2013-2023

Source: Author contribution in JASP19

The order of these associations is of particular analytical interest. At the bivariate level, innovation appears as the weakest correlation predictor of employment, and the ICT sector has a higher association with it. An interpretation based solely on correlations would conclude that digital sector specialization is a more promising channel than systemic innovation capacity.

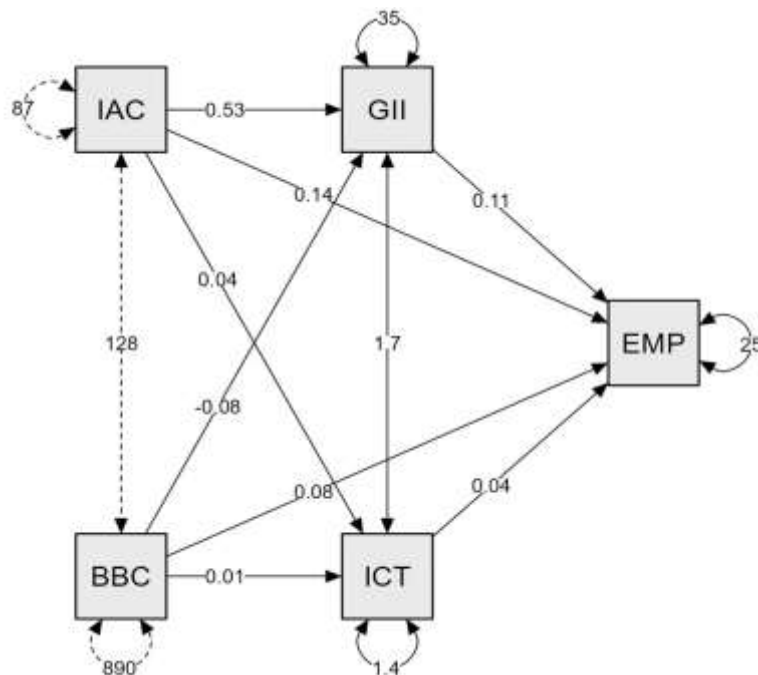


Figure No. 2. Mediation analysis through SEM, EU-27, 2013-2023

Source: Author contribution in JASP19

Both components of the digital infrastructure have a positive influence (Figure No. 2) on the occupancy rate, but their hierarchy is reversed depending on the metric: internet access has the highest non-standardized coefficient (0.142 versus 0.081), while broadband coverage exerts the strongest standardized effect of the model ($\beta = 0.396$ compared to $\beta = 0.217$), as a consequence of its considerably higher dispersion. The two metrics answer distinct questions, the marginal yield of an intervention and the contribution to explaining the observed variation, both of which are relevant to public policy.

Performance in innovation positively influences employment ($\beta = 0.130$; $p = 0.040$), with a modest magnitude and a marginal significance, consistent with the literature on compensation (Vivarelli, 2015). The contribution of the ICT sector does not show a detectable effect ($\beta = 0.009$; $p = 0.901$); the standard error of 0.337, more than twenty-five times higher than that of the BBC $\rightarrow$ EMP path, reflects the incomplete coverage and low dispersion of the variable, so that the result indicates the impossibility of distinguishing a zero effect, and not its demonstrated absence.

Internet access is the strongest predictor of innovation performance ($\beta = 0.673$; $p < 0.001$). However, broadband coverage has a negative association with it ($\beta = -0.317$; $p < 0.001$), contrary to theoretical expectation. The contrast with the null bivariate correlation ($r = -0.009$) identifies the result as a suppression effect: conditioned by the effective access of households, the expansion of infrastructure coverage is associated with a lower performance in innovation. Both predictors positively influence the size of the ICT sector ($\beta = 0.256$ and $\beta = 0.280$ respectively), without this effect being passed on to employment.

Table No. 3. Coefficients of the structural model

							95% Confidence Interval	
			Estimate	Std. Error	z-value	p	Lower	Upper
ICT	$\rightarrow$	EMP	0.042	0.337	0.125	0.901	-0.619	0.703
GII	$\rightarrow$	EMP	0.107	0.052	2.058	0.040	0.005	0.208
BBC	$\rightarrow$	EMP	0.081	0.013	6.392	< 0.001	0.056	0.106
IAC	$\rightarrow$	EMP	0.142	0.044	3.224	0.001	0.056	0.228
BBC	$\rightarrow$	ICT	0.012	0.003	3.600	< 0.001	0.005	0.018
IAC	$\rightarrow$	ICT	0.035	0.010	3.481	< 0.001	0.015	0.055
BBC	$\rightarrow$	GII	-0.079	0.013	-6.010	< 0.001	-0.105	-0.053
IAC	$\rightarrow$	GII	0.535	0.042	12.772	< 0.001	0.453	0.617

Note. Delta method standard errors, normal theory confidence intervals, ML estimator.

Source: Author contribution in JASP19

The indirect effect of transmitted internet access through innovation performance is 0.057 ($\beta = 0.088$), representing 28.5% of the total effect of 0.307. Since the direct effect remains significant and the two components have the same sign, the configuration corresponds to a partial complementary mediation (Zhao, Lynch, & Chen, 2010): the proposed mechanism operates, but about three-quarters of the connectivity effect is transmitted through channels that do not involve innovation. H1 is confirmed.

The equivalent route for broadband coverage has a qualitatively different structure. The indirect effect is negative (-0.008; $\beta = -0.041$), while the direct effect remains positive and substantial ($\beta = 0.396$), a configuration that defines competitive mediation. About 10% of the direct contribution of employment coverage is cancelled out through the innovation pathway. H2 is confirmed, with the specification that the identified mediation operates in the opposite direction to that anticipated by the reference literature.

Both pathways involving the ICT sector produce virtually zero indirect effects ($\beta = 0.002$ and $\beta = 0.003$), representing less than one percentage of the corresponding total effects. Although the input segments are statistically significant, the digital infrastructure effectively determines the size of the ICT sector, the complete chain does not transmit an effect, as the terminal segment is insignificant. H3 and H4 are rejected.

The results thus set up a double asymmetrical pattern. On the dimension of mediators, systemic innovation capacity conveys the effect of connectivity on employment, while digital sector specialization does not. On the predictor dimension, mediation through innovation operates in the case of effective and competitive access in the case of infrastructure coverage. The two components of digitalization are therefore not interchangeable measures of the same phenomenon.

5.

6. Conclusions

This study examined whether innovation performance mediates the relationship between digital connectivity and employment across EU Member States. Starting from the finding that the literature consistently documents the existence of a relationship between digitalization and labor market outcomes, but insufficiently addresses the mechanisms through which it operates, the analysis tested two competing transmission channels, systemic innovation capacity and digital sectoral specialization, on a panel comprising the 27 Member States in the period 2013-2023.

The results support three conclusions. Firstly, innovation is a genuine transmission channel, but only partially: the indirect effect of internet access accounts for around 28% of the total effect, with the rest being transmitted through untested mechanisms in this model. Secondly, effective access and infrastructure coverage operate through distinct channels. The negative association between broadband coverage and innovation performance configures a competitive mediation and provides a macroeconomic translation of the distinction between the levels of the digital divide (van Deursen and van Dijk, 2019). Third, the expansion of the ICT sector is not a channel of employment: although digital infrastructure significantly determines its size, it does not transmit the effect to aggregate employment, and the positive bivariate association is attributable to the common determination by the degree of connectivity.

7. References

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