Mačiulytė-Šniukienė, A., Dargenytė-Kacilevičienė, L., & Matuzevičiūtė, K. (2023). Convergence in transport and ICT infrastructure: Evidence of EU member states. *Journal of International Studies, 16*(4), 77-96. doi:10.14254/2071-8330.2023/16-4/6

Journal of International Studies

Centre of Sociological Research

Scientific Papers

Convergence in transport and ICT infrastructure: Evidence of EU member states

Alma Mačiulytė-Šniukienė
Department of Business Technology and Entrepreneurship, Faculty of Business Management, Vilnius Gediminas Technical University, Vilnius, Lithuania
a.maciulyte-sniukiene@vilniustech.lt
ORCID 0000-0001-6661-7407

Laura Dargenytė-Kacilevičienė
Institute of Regional Development, Šiauliai Academy, Vilnius University, Šiauliai, Lithuania
laura.dargenyte-kaciieviciene@sa.vu.lt
ORCID 0000-0002-8552-8829

Kristina Matuzevičiūtė
Department of Economics Engineering, Faculty of Business Management, Vilnius Gediminas Technical University, Vilnius, Lithuania
kristina.matuzeviciute-balciuniene@vilniustech.lt
ORCID 0000-0003-0573-0072

Received: March, 2023
1st Revision: September, 2023
Accepted: December, 2023

DOI: 10.14254/2071-8330.2023/16-4/6

Abstract. While countries' social and economic well-being depends on various factors, recent research emphasises the importance of transport and ICT infrastructure. To reduce the welfare differences among EU countries, the European Commission and governments have to ensure the convergence of this infrastructure as well. Previous studies have shown that convergence is taking place at the national level, however the situation at the regional level still needs to be determined. In light of this, the study examines transport and ICT infrastructure convergence in EU member states and NUTS 2 regions at different periods. The research methodology is based on the neoclassical approach of convergence, i.e., β-convergence model presented by Barro and Sala-i-Martin (1992). This approach is deemed most appropriate for determining whether the disparities in terms of infrastructure among EU members and regions are diminishing. Research findings present clear evidence of absolute β-convergence in infrastructure development across EU member states and NUTS 2 regions. Strong evidence of transport convergence is identified among EU member states and among NUTS 2 regions, however, it is observed only in one out of the three types of infrastructure. In contrast, the robust evidence of ICT infrastructure convergence is prominent across EU countries and NUTS 2 regions, showcasing substantial reductions in disparities.

Keywords: infrastructure convergence, transport infrastructure, ICT infrastructure, EU, NUTS 2 regions

JEL Classification: D83, O18, O47

1. INTRODUCTION

The literature on economic convergence has drawn a lot of attention over the last decades. However, there is scarce research on the convergence in infrastructure despite that core infrastructure has always been regarded as an important component of the EU integration process, as it plays an important role in regional economic development (Wang et al., 2020; Wang et al., 2020). Usually, previous studies analyse infrastructure as the factor leading to higher economic growth (Meersman & Nazemzadeh, 2017; Pandya & Maind, 2017; Wang et al., 2020; Zhang et al., 2019; Cong et al., 2020; Pasha et al., 2020; Maciulyte-Sniukiene & Butkus, 2022; Mačiulytė-Šniukienė, Butkus, & Davidavičienė, 2022), productivity (Dedrick et al., 2013; C. Wang et al., 2020), or regional convergence (Fageda & Olivieri, 2019; Mačiulytė-Šniukienė, Butkus, & Davidavičienė, 2022) neglecting the topic of the convergence of infrastructure. Moreover, research usually assesses the convergence of only one type of infrastructure, i.e. transport infrastructure (Beyzatlar & Yetkiner, 2017; Kot & Ojinji 2023) or ICT convergence (Park et al., 2015; Kathuria & Oh, 2018; Rath et al., 2023; Saba & David, 2022).

There are only a few research analysing transport infrastructure convergence. Beyzatlar and Yetkiner (2017) examined the convergence in transportation measures in EU-15 countries for the period 1970–2013 applying difference GMM and System GMM methods. The results provide solid evidence that there is absolute and conditional convergence between the EU-15 countries in two transport measures: inland freight transportation per capita and inland passenger transportation per capita. These estimates show that convergence is even stronger when controlling variables such as GDP per capita, urbanization, openness, and inward FDI stock are included in the model. The authors state that the convergence of transport in the EU-15 also reflects the success of this integration policy in transport and that economic convergence feeds back into transport convergence as well. The other research by Saba (2021) covers 102 countries throughout 1990–2018 period. The Phillips and Sul econometric convergence method was applied to test club convergence and to model transition paths toward convergence in this research. The main conclusions of the study suggest the existence of convergence at the global and regional levels (except for Africa, Europe, and Oceania, which exhibited divergence) which shows that transport-poor countries are catching up with transport-rich countries. As a result, it would be possible to enable less developed countries not to pay the costs associated with initial learning, implementation and assessment of transport infrastructure. A similar research was conducted by Saba et al. (2021) which analysed three indicators of transportation infrastructure: air transport, freight; roads total network (km); and rail lines (total route-km) from 1990 to 2018 for the 102 countries confirmed convergence to the same steady state under the full sample. The study also found that the speed of panel convergence rates differs among analysed country groups.

The other kind of infrastructure that plays a key role in economic growth is ICT infrastructure and as Saba and David (2020) state the convergence of ICTs ensures efficiency in resource allocation and promotes economic growth. The authors analysed 205 countries over the period 2000–2018 applying Phillips and Sul econometric methodology. The results identified the existence of club convergence in the analysed sample and that countries are moving toward convergence, and the speed of convergence is strong, however, less developed regions, i.e. Sub-Saharan Africa, do not converge to the same steady state. Similar results we conducted by Kathuria and Oh (2018), indicating differences between analysed regions in terms of σ and β convergence across 98 countries for the period from 2000 to 2015. Results of σ convergence imply that European and North American countries have made significant progress in terms of ICT access, achieving both absolute and relative convergence, resulting in a real catch-up. In other regions, there has been an increase in the digital divide in terms of absolute measures. The estimations of β convergence that is positive, suggesting that countries that had lower initial levels of ICT are experiencing faster digital access compared to those with higher initial access. This indicates a decrease in the digital divide. The study by Park (2015) examining ICT data from 108 countries over the period 2000 – 2012 categorized countries into three groups and identified the difference in convergence speed among these groups. Group 1 had the highest level of digitalization, but the convergence was the slowest compared to the other two groups. On the other hand, group 3 had the fastest convergence rate among the three groups, despite having the lowest level of agreement in digitalization. A country's probability of being in a higher convergence level increases as the per capita GDP, tertiary education entrance rate, and the share of service trade in GDP values increase. Conversely, the ratio of urban population is inversely related to the convergence level, meaning that as the ratio of urban population increases, the probability of being in a higher convergence level decreases. Research by Rath et al. (2023) indicated that emerging market countries are converging among themselves and 'catching up' to the OECD countries in terms of convergence of ICT over the period 2000–2018. Authors also conclude that in the case of emerging market countries, per capita income, human capital, and FDI are significant factors that have an impact on the development of ICT. Koski and Majumdar (2000) examining the telecommunications sector in OECD countries over the period 1980–1995 indicated slower σ convergence during the first half of the 1990s than they did during the 1980s. This could be due to the reason that at the beginning of the 1990s, the OECD countries which were initially lagging in terms of their fixed and mobile services provision, as well as the modernization and quality of their fixed telecommunications networks. However, the results do not support the existence of β convergence which indicates that the ranking of OECD countries in terms of providing efficient telecommunications infrastructure has remained relatively consistent, but the range of differences in this distribution has decreased over time.

We can conclude that transport infrastructure is the key factor for economic and productivity growth or even convergence processes but there is a lack of research analysing transport and ICT infrastructure convergence that could reduce regional disparities and promote economic growth.

2. METHODOLOGICAL APPROACH

Different concepts of convergence are applied to evaluate the process of infrastructure convergence in countries and regions, i.e., the absolute β-convergence (Beyzatlar & Yetkiner, 2017; Koski & Majumdar, 2000), conditional β-convergence (Beyzatlar & Yetkiner, 2017), σ-convergence (Koski & Majumdar, 2000; Kathuria & Oh, 2018) and the club convergence (Park et al., 2015; Saba & David, 2020; Saba et al., 2021; Saba, 2021; Rath et al., 2023). As it was stated in the research of Butkus et al. (2018), although the different concepts of convergence are related, each one corresponds to different aspects of the same process. Therefore, it is crucial to consider what is being measured by a particular convergence index. Our research intends to investigate the convergence of ICT and transport infrastructure among EU Member states and NUTS 2 regions determining whether the disparities in terms of infrastructure among EU members and regions are diminishing. For that purpose, we apply the neoclassical approach of convergence, i.e., β-convergence model presented by Barro, Sala-i-Martin (1992). Our estimations are based on two equations. The first equation describes the absolute β-convergence:

$$\frac{1}{T-t-1}\ln\left(\frac{INF_{T,i}}{INF_{t,i}}\right) = \alpha + \beta \cdot \ln\left(INF_{t,i}\right) + \varepsilon_i, \quad (1)$$

where $\frac{1}{T-t-1}\ln\left(\frac{INF_{T,i}}{INF_{t,i}}\right)$ is the annual growth rate of infrastructure variable (ICT or transport) in the country or NUTS 2 region *i* over the period from *t* up to T. INF_t is the initial level of infrastructure variable (ICT or transport). α and β are the coefficients to be estimated, ε_i is the error term. β is expected to be negative, meaning that the ICT and transport infrastructure convergence among EU Member states and NUTS 2 regions exists.

To make our estimation results more reliable, we use three variables to measure the transport infrastructure, i.e. *MOT* (motorways, km. per thousand square km.), *RLW* (total railway lines, km. per thousand square km.) and *AIR* (air transport of passengers, passengers carried, thousand passengers). To measure the ICT infrastructure, we use two variables – *INT* (households with access to the internet at home, % of households) and *BRD* (households with broadband access, % of households). Estimations are made using data collected from Eurostat. Additionally, we aim to analyze if ICT and transport convergence exists during the different periods of EU Structural Funds financial support. For that purpose, transport infrastructure convergence is estimated separately for the periods 2000–2006, 2007–2013, 2014–2019, and the whole period 2000–2019. ICT infrastructure convergence is estimated separately for the periods 2007–2013, 2014–2019, and the whole period 2007–2019. 2000–2006 for ICT infrastructure convergence and the year 2020 of EU Structural Funds financial support are not included in estimations due to the lack of data.

Since countries and regions have different initial conditions (Butkus et al., 2018), the other uncontrolled variables could impact β-convergence. The authors investigating transport and ICT infrastructure convergence (Park et al., 2015; Beyzatlar & Yetkiner, 2017; Rath et al., 2023) relied on standard income convergence literature and included additional variables in their estimations. Beyzatlar and Yetkiner (2017) singled out such key factors as GDP per capita, urbanization (urban population), trade openness, and inward foreign direct investment (FDI) stock. Park (2015) controlled variables such as GDP per capita, tertiary education entrance rate, urban population, and the share of service trade in GDP. Per capita income, human capital, inward FDI flaws, ICT exports of goods and services, financial development, and urbanization rate variables were included in the research of Rath et al. (2023).

Among variables that could have a positive impact on the ICT infrastructure development is economic growth (Nair et al., 2020; Pradhan, 2019; Pradhan et al., 2021; Sawng et al., 2021; Roger et al., 2022), GDP per capita (Farooqi, 2020), R&D (Lee et al., 2016; Nair et al., 2020), urbanization (Cohen-Blankshtain & Rotem-Mindali, 2016; Farooqi, 2020; Pradhan et al., 2021), inward FDI flaws (Arvin & Pradhan, 2014; Samir & Mefteh, 2020), institutional quality (Farooqi, 2020), education and trade openness (Lee et al., 2016). Variables such as economic growth (Maparu & Mazumder, 2021; Pradhan et al., 2021; Sarania, 2021), urbanization (Maparu & Mazumder, 2021; Pradhan et al., 2021), institutional quality (Di Liddo et al., 2019; Cavalieri et al., 2020), trade openness (Sarania, 2021) and inward FDI stock (Samir & Mefteh, 2020) are discussed as ones which can also encourage the development of transport infrastructure.

To address the issue of uncontrolled variables in the absolute β-convergence model, we apply the second equation, which describes the conditional β-convergence:

$$\frac{1}{T-t-1}\ln\left(\frac{INF_{T,i}}{INF_{t,i}}\right) = \alpha + \beta \cdot \ln\left(INF_{t,i}\right) + \gamma \cdot \overline{X_{\iota,t\rightarrow T}} + \varepsilon_i, \quad (2)$$

$\overline{X_{\iota,t\rightarrow T}}$ is the mean value of the control variable in the country or NUTS 2 region i over the period from t up to T.

As the other authors mentioned above, we include various control variables that proxy economic development, innovation and technology development, urbanization, education, institutional quality, and economic openness. Economic development is approximated by GDP per capita at constant 2015 prices. We used the price index (implicit deflator), 2015 = 100, euro, to correct the changes in price levels over time. The variable is expressed in a logarithm (*Ln_Y*). To proxy the innovation and technology development (*R&D*) we use expenditure on R&D, % of GDP variable. Since urban population data is not collected at the NUTS 2 regional level, urbanization differs from other research (Park et al., 2015; Beyzatlar & Yetkiner, 2017; Rath et al., 2023) and is approximated by population density (*Ln_POP),* people per sq. km of land area. As stated by (Potere & Schneider, 2007; United Nations, 2011), the level of urbanization could be expressed by demographic characteristics like population density. Institutional quality at the NUTS 2 regional level is approximated by the quality sub-index (*IQ*) of the European Quality of Government Index (EQI). At the country level, institutional quality is measured by two variables, i.e., government effectiveness (*IQ (1)*) and voice and accountability (*IQ (2)*) indexes from World Bank's World Governance Indicators. According to the structure of EQI, the quality sub-index is based on the mean of these two indexes (Charron et al., 2021). Economic openness is approximated by trade, % of GDP (*OPEN*) and FDI, net inflows, % of GDP (*FDI*). Education (*EDU*) is measured by population with tertiary education (age from 25 to 64 years), %.

Data on GDP per capita, education, and expenditure on R&D are collected from Eurostat. Data on population density, FDI, trade openness – from World Bank database. The summary statistics of variables used in estimations of ICT convergence are presented in Table 1. The summary statistics of variables used in estimations of transport convergence are presented in Table 2. The Ordinary Least Squares (OLS) method is used to estimate the ICT and transport convergence in EU Member states and NUTS 2 regions. The heteroscedasticity robust standard errors are included in all estimations.

Table 1

The summary statistics of variables used to estimate ICT infrastructure convergence

2007–2019					
Regional level (NUTS 2)					
Notion	**Variable**	**Average**	**Min**	**Max**	**St. Dev.**
Dependent variables					
INT	Households with access to the internet at home (% of households)	74.76	17.0	100.0	16.43
BRD	Households with broadband access (% of households)	70.18	9.0	100.0	18.60
Control variables					
Ln_Y	Gross domestic product (GDP) per capita at constant 2015 prices	10.01	8.15	11.52	0.62
Ln_POP	Population density (people per sq. km of land area)	4.97	1.12	8.93	1.19
R&D	GERD (Gross domestic expenditure on R&D), % of GDP	1.38	0.06	9.35	1.19
EDU	Population by educational attainment level, tertiary education (age from 25 to 64 years), %	26.38	6.80	58.40	9.06
IQ	European Quality of Government Index (quality sub-index)	-0.03	-3.16	3.31	1.00
Country level					
Dependent variables					
INT	Households with access to the internet at home (% of households)	73.26	18.96	98.41	16.23
BRD	Households with broadband access (% of households)	68.36	7.46	97.92	18.73
Control variables					

Ln_Y	Gross domestic product (GDP) per capita at constant 2015 prices	10.00	8.59	11.53	0.65
Ln_POP	Population density (people per sq. km of land area)	4.67	2.86	7.36	0.90
R&D	GERD (Gross domestic expenditure on R&D), % of GDP	1.55	0.38	3.73	0.89
EDU	Population by educational attainment level, tertiary education (age from 25 to 64 years), %	4.67	2.86	7.36	0.90
IQ (1)	Government Effectiveness Index: Estimate	1.09	-0.37	2.35	0.58
IQ (2)	Voice and Accountability Index: Estimate	1.09	0.31	1.69	0.34
OPEN	Trade, % of GDP	126.17	45.42	377.84	65.68
FDI	Foreign direct investment, net inflows (% of GDP)	12.76	-57.53	449.08	40.61

Source: *own compilation*

Table 2

The summary statistics of variables used to estimate transport infrastructure convergence

2000–2019					
Regional level (NUTS 2)					
Notion	**Variable**	**Average**	**Min**	**Max**	**St. Dev.**
Dependent variables					
MOT	Road, rail and navigable inland waterways networks (motorways, km. per thousand square km.)	28.10	0.0	191.0	29.36
RLW	Road, rail and navigable inland waterways networks (total railway lines, km. per thousand square km.)	69.44	0.0	708.0	81.39
AIR	Air transport of passengers (passengers carried, thousand passengers)	6.37×10^3	0.0	6.37×10^5	1.2×10^4
Control variables					
Ln_Y	Gross domestic product (GDP) per capita at constant 2015 prices	9.96	7.81	11.52	0.65
Ln_POP	Population density (people per sq. km of land area)	4.96	1.12	8.93	1.19
IQ	European Quality of Government Index (quality sub-index)	-0.03	-3.16	3.31	1.01
Country level					
Dependent variables					
MOT	Road, rail and navigable inland waterways networks (motorways, km. per thousand square km.)	20.34	0.0	82.00	19.63
RLW	Road, rail and navigable inland waterways networks (total railway lines, km. per thousand square km.)	56.03	17.00	127.00	31.07
AIR	Air transport of passengers (passengers carried, thousand passengers)	3.70×10^4	362.00	2.28×10^5	5.08×10^4
Control variables					
Ln_Y	Gross domestic product (GDP) per capita at constant 2015 prices	9.94	8.12	11.52	0.69
Ln_POP	Population density (people per sq. km of land area)	4.67	2.83	7.36	0.89
IQ (1)	Government Effectiveness Index: Estimate	1.10	-0.37	2.35	0.61
IQ (2)	Voice and Accountability Index: Estimate	1.11	0.30	1.80	0.34
OPEN	Trade, % of GDP	118.31	45.42	377.84	62.10
FDI	Foreign direct investment, net inflows (% of GDP)	12.35	-57.53	449.08	39.65

Source: *own compilation*

3. CONDUCTING RESEARCH AND RESULTS

Empirical findings revealed that absolute β-convergence in terms of infrastructure development among EU Member states and NUTS 2 regions is present. However, results vary across different infrastructure variables and periods of EU Structural Funds financial support. The presence of negative and statistically significant β coefficients suggests that countries and regions with less advanced infrastructure tend to experience faster infrastructure growth compared to those with higher initial levels of infrastructure.

During the 20 years the average speed of transport infrastructure (measured by motorways, km. per thousand square km.) convergence was about 1.6 % among EU Member states (see Table 3) and about 1.3 % among NUTS 2 regions (see Table 4). However, the convergence process is not developing in all considered transport sectors. For example, the convergence process was not confirmed in the cases, when transport infrastructure was measured by total railway lines or air transport of passengers. This implies that financial support of EU Structural Funds for transport development may be allocated unevenly or inefficiently.

More detailed analysis also showed that there are no significant differences in transport infrastructure convergence among NUTS 2 regions during different periods of EU Structural Funds financial support with one exception. Results suggest that there was strong evidence of transport infrastructure (measured by thousand passengers of air transport carried) convergence among NUTS 2 regions during the period of 2000–2006 but afterward, this tendency stopped. The highest transport infrastructure convergence (measured by motorways, km. per thousand square km.) speed (about 3.2 %) among EU countries was reached from 2007 to 2013 EU funding. The estimated convergence coefficient for the period 2000–2006 was insignificant regardless of the chosen transport infrastructure variable. It is also can be seen that between 2014 and 2019, some transport convergence (measured by thousand passengers of air transport carried) evidence was detected among EU Member states. Our results are in line with Beyzatlar and Yetkiner (2017) who also confirmed the existence of transport infrastructure convergence among the EU-15 countries and with other authors (Saba, 2021; Saba et al., 2021) who confirmed that transport-poor countries are catching up with transport-rich countries.

The more robust evidence of existing infrastructure convergence is revealed in terms of ICT infrastructure development. β-convergence is very strong among EU countries and NUTS 2 regions regardless of the chosen variable or period of time. The average speed of ICT infrastructure convergence during the whole period 2007–2019 ranged from 7 % to 7.6 %. The average convergence speed during the different periods of EU financial support ranged from 9.7 % to 13.1 % and was quite similar for EU Member states compared to NUTS 2 regions. The magnitude of ICT convergence among EU countries and regions is high meaning that the disparities in terms of ICT among EU Members and regions are rapidly diminishing. Also, our results suggest that the ICT convergence (measured by households with broadband access as % of households) between 2014 and 2019 has lost its speed but the speed of ICT convergence (measured by households with access to the internet at home as % of households) increased. These results support the idea that the digital divide among EU countries or NUTS 2 regions is decreasing as in other countries or groups of countries in the world which is in line with previous research (Saba & David, 2020; Kathuria & Oh, 2018; Park et al., 2015).

Table 3

Infrastructure convergence among EU Member States

Infrastructure	Variable	2000–2006	2007–2013	2014–2019	2000–2019
Transport	Motorways (MOT)	−0.014	−0.032***	−0.011**	−0.016***
		(0.009)	(0.008)	(0.005)	(0.005)
	Obs.	22	24	24	22
	Railways (RLW)	−0.003	−0.001	−0.003	−0.002
		(0.004)	(0.005)	(0.002)	(0.002)
	Obs.	23	24	24	23
	Air transport (AIR)	−0.020	−0.003	−0.012***	−0.010*
		(0.018)	(0.005)	(0.003)	(0.005)
	Obs.	10	26	27	10
	Variable	**2000–2006**	**2007–2013**	**2014–2019**	**2007–2019**
ICT	Internet (INT)		−0.099***	−0.113***	−0.071***
			(0.004)	(0.009)	(0.002)
	Obs.		27	27	27
	Broadband (BRD)		−0.131***	−0.110***	−0.076***
			(0.004)	(0.010)	(0.001)
	Obs.		26	27	27

Note. The table represents estimated β coefficients for different transport or ICT infrastructure indicators separately. Heterostedasticity robust standard errors are represented in parentheses. *, **, *** indicate significance at the 10, 5, and 1 percent level, respectively.

Table 4

Infrastructure convergence among NUTS 2 regions

Infrastructure	Variable	2000–2006	2007–2013	2014–2019	2000–2019
Transport	Motorways (MOT)	−0.017***	−0.016***	−0.015***	−0.013***
		(0.005)	(0.007)	(0.004)	0.003
	Obs.	129	145	100	74
	Railways (RLW)	−0.004	−0.003	−0.003	0.001
		(0.004)	(0.004)	(0.002)	(0.002)
	Obs.	84	128	113	69
	Air transport (AIR)	−0.021***	−0.008	0.004	0.001
		(0.007)	(0.003)	(0.003)	(0.003)
	Obs.	72	157	166	84
	Variable	**2000–2006**	**2007–2013**	**2014–2019**	**2007–2019**
ICT	Internet (INT)		−0.097***	−0.120***	−0.070***
			(0.004)	(0.004)	(0.001)
	Obs.		75	155	75
	Broadband (BRD)		−0.125***	−0.118***	−0.072***
			(0.003)	(0.005)	(0.001)
	Obs.		75	155	75

Note. The table represents estimated β coefficients for different transport or ICT infrastructure indicators separately. Heterostedasticity robust standard errors are represented in parentheses. *, **, *** indicate significance at the 10, 5, and 1 percent level, respectively.

Following the idea, that other initial conditions of countries and regions could change the convergence ratio or even increase it (Beyzatlar & Yetkiner, 2017), we include other variables in our calculations. Differently from Beyzatlar and Yetkiner (2017), we do not find that all of the control variables are associated with increased convergence speed. Results of conditional β-convergence of transport infrastructure show that the key factor changing the speed of convergence among EU Members is population density which is the measure of urbanization. Due to the inclusion of this factor, the speed of convergence increased from 1.6% to 2.9 % during the whole period (see Table A in Appendices), from 3.2% to 4.9% during the period of 2007–2013 (see Table C), and increased from 1.1% to 2.2% during the period 2014–2019 (see Table D). The convergence process also became strong (3.3%) and statistically significant during the period of 2000–2006 (see Table B). Other variables such as institutional quality, economic openness and foreign direct investment have no impact on the speed of transport infrastructure convergence among EU countries and barely have an impact on transport infrastructure development at all.

The same tendencies are revealed by analysing the transport infrastructure convergence among NUTS 2 regions. During the whole analysed period, the convergence speed increased from 1.3% to 2.2% due to the inclusion of the population density variable into the equation (see Table E). The same is during all periods of EU programming funding. These results suggest that countries and regions with higher population density might prioritize and invest more in improving their transportation systems due to higher demand. Conclusions about the effect of income and institutional quality on the development of transport and the speed of convergence are not unambiguous and depend on the chosen research period and transport infrastructure indicator. Differently from the EU Member States context, empirical results suggest that from 2000 to 2019, due to the inclusion of variables that measure economic development and institutional quality, the convergence speed among NUTS 2 regions slightly decreased from 1.3% on average to 0.65% on average. Going into more detail, it seems that a higher level of income and institutional quality is positively correlated with the infrastructure development of railways (except from 2014 to 2019) and negatively with the infrastructure development of air transport and motorways). It is in line with Zhang and Graham (2020) study results that revealed only one direction of causality between GDP and air transport, which runs from air transport to economic growth. The negative correlation between income and motorways is unexpected but logical. Generally, EU countries with lower income invest in developing motorways from EU Structural Funds. The higher the country's GDP, the less EU support it receives, and therefore, the less it invests in motorways infrastructure.

Further analysis shows that different from the case of transport infrastructure, higher income either boosts the ICT development or is associated with increased speed of ICT convergence among EU countries during the whole analysed period and the 2014–2019 period (see Table F). Other factors such as technology development and education despite their minor impact on ICT development are also associated with the increased speed of ICT infrastructure convergence. These results support the findings by Park et al. (2015) who revealed that a country's probability of being in a higher ICT infrastructure convergence level is associated with higher per capita GDP and tertiary education entrance rate.

Analysis of conditional ICT convergence among NUTS 2 regions revealed that during the whole analysed period (2007–2019) two factors i.e. institutional quality and education had a minor but positive impact on ICT development (measured by households with access to the internet at home as % of households) (see Table G). Controlling of these variables minimally but the speed of ICT infrastructure convergence increased as well. More detailed analysis showed that during different periods of EU Structural Funds financial support the main factors that have an impact on ICT infrastructure development and increase the speed of ICT infrastructure convergence are economic development, technology development, institutional quality and education. Following our results, we can state that technological development was more important between 2007 and 2013 while between 2014 and 2019, education found its place.

CONCLUSION

In recent years, economic convergence literature has gained prominence, yet research on infrastructure convergence is still very scarce. Despite infrastructure's role in EU integration and regional development, studies often focus on economic growth, productivity, or regional disparities, overlooking broader infrastructure convergence. Research has touched on transport and ICT infrastructure convergence, revealing encouraging signs of convergence among EU-15 countries and globally, showcasing the reciprocal relationship between economic and transport convergence. ICT convergence also emerged as a key driver of economic growth and resource efficiency. Overall, addressing the gap in infrastructure convergence research our study aims to examine transport and ICT infrastructure convergence in EU Member states and NUTS 2 regions.

Our empirical findings present clear evidence of absolute β-convergence in terms of infrastructure development across EU Member states and NUTS 2 regions. However, the extent of convergence varies among different infrastructure variables and programming periods. Negative and statistically significant β coefficients indicate that less developed infrastructure leads to faster infrastructure growth. Transport infrastructure convergence exhibited diverse outcomes, with some sectors showing convergence and others not. Despite variations, the results indicated that EU Structural Funds allocation for transport development might require a more balanced distribution. While some transport infrastructure convergence was observed among NUTS 2 regions, strong evidence of convergence was evident among EU Member states, particularly during certain periods.

In contrast, the robust evidence of ICT infrastructure convergence was prominent across both EU countries and NUTS 2 regions, showcasing substantial reductions in disparities. ICT convergence displayed consistent trends over different periods and variables, suggesting that the digital divide within the EU is diminishing. The role of various factors, such as income, education, and technology development, was confirmed in influencing the pace of ICT convergence.

Furthermore, the influence of other variables on the convergence process was explored, with population density emerging as a key factor affecting transport infrastructure convergence among EU Member states. Other control variables were found to influence transport and ICT development, although impacts varied based on specific indicators and timeframes.

In conclusion, the study provides valuable insights into infrastructure convergence dynamics within the EU. The presence of convergence underscores the significance of addressing initial disparities, and the findings have implications for the targeted allocation of EU Structural Funds to ensure efficient infrastructure development. Moreover, the study highlights the consistent progress of ICT infrastructure convergence, which aligns with broader trends in reducing digital disparities. The identified factors influencing convergence emphasize the complex interplay of economic, social, technological, and institutional aspects in shaping infrastructure development trajectories.

ACKNOWLEDGEMENT

This research is a part of the project on the Evaluation of the Interaction Between Economic Growth and Infrastructure Development in the European Union Member States (IP&EASVES). This project has received funding from European Social Fund (project No. 09.3.3-LMT-K-712-19-0036) under a grant agreement with the Research Council of Lithuania (LMTLT).

REFERENCES

Allen, T., & Arkolakis, C. (2022). The Welfare Effects of Transportation Infrastructure Improvements. *The Review of Economic Studies*, *89*(6), 2911–2957. https://doi.org/10.1093/restud/rdac001

Arvin, B. M., & Pradhan, R. P. (2014). Broadband penetration and economic growth nexus: Evidence from cross-country panel data. *Applied Economics*, *46*(35), 4360–4369. https://doi.org/10.1080/00036846.2014.957444

Barro, R. J., & Sala-i-Martin, X. (1992). Convergence. *Journal of Political Economy*, *100*(2), 223–251.

Beyzatlar, M. A., & Yetkiner, H. (2017). Convergence in transportation measures across the EU-15. *Transportation*, *44*(5), 927–940. https://doi.org/10.1007/s11116-016-9686-6

Butkus, M., Cibulskiene, D., Maciulyte-Sniukiene, A., & Matuzeviciute, K. (2018). What Is the Evolution of Convergence in the EU? Decomposing EU Disparities up to NUTS 3 Level. *Sustainability*, *10*(5), 1552. https://doi.org/10.3390/su10051552

Cavalieri, M., Guccio, C., Lisi, D., & Rizzo, I. (2020). Does Institutional Quality Matter for Infrastructure Provision? A Non-parametric Analysis for Italian Municipalities. *Italian Economic Journal*, *6*(3), 521–562. https://doi.org/10.1007/s40797-019-00111-1

Charron, N., Lapuente, V., & Bauhr, M. (2021). Sub-national Quality of Government in EU Member States: *2021*.

Cohen-Blankshtain, G., & Rotem-Mindali, O. (2016). Key research themes on ICT and sustainable urban mobility. *International Journal of Sustainable Transportation*, *10*(1), 9–17. https://doi.org/10.1080/15568318.2013.820994

Cong, L., Zhang, D., Wang, M., Xu, H., & Li, L. (2020). The role of ports in the economic development of port cities: Panel evidence from China. *Transport Policy*, *90*, 13–21. https://doi.org/10.1016/j.tranpol.2020.02.003

Dedrick, J., Kraemer, K. L., & Shih, E. (2013). Information Technology and Productivity in Developed and Developing Countries. *Journal of Management Information Systems*, *30*(1), 97–122. https://doi.org/10.2753/MIS0742-1222300103

Di Liddo, G., Rubino, A., & Somma, E. (2019). Determinants of PPP in infrastructure investments in MENA countries: A focus on energy. *Journal of Industrial and Business Economics*, *46*(4), 523–580. https://doi.org/10.1007/s40812-019-00129-7

Donaldson, D. (2018). Railroads of the Raj: Estimating the Impact of Transportation Infrastructure. *American Economic Review*, *108*(4/5), 899–934. https://doi.org/10.1257/aer.20101199

Fageda, X., & Olivieri, C. (2019). Transport infrastructure and regional convergence: A spatial panel data approach. *Papers in Regional Science*, *98*(4), 1609–1631. https://doi.org/10.1111/pirs.12433

Farhadi, M. (2015). Transport infrastructure and long-run economic growth in OECD countries. *Transportation Research Part A: Policy and Practice*, *74*, 73–90. https://doi.org/10.1016/j.tra.2015.02.006

Farooqi, Z., Yaseen, M. R., Anwar, S., & Makhdum, M. S. A. (2020). Determinants of information of *Science and Technology*, *13*(39), 4116–4126. https://doi.org/10.17485/IJST/v13i39.797

Gibson, J., & Rioja, F. (2020). The welfare effects of infrastructure investment in a heterogeneous agents economy. *The B.E. Journal of Macroeconomics*, *20*(1). https://doi.org/10.1515/bejm-2019-0095

Głębocki, K. (2021). Planning cooperation between city government and ICT firms in the context of smart city concept. *Polish Journal of Management Studies*, *24*(1), 112-125. https://doi.org/ 10.17512/pjms.2021.24.1.07

Jayaprakash, P., & Pillai, R. R. (2021). The Role of ICT and Effect of National Culture on Human Development. *Journal of Global Information Technology Management*, *24*(3), 183–207. https://doi.org/10.1080/1097198X.2021.1953319

Kallal, R., Haddaji, A., & Ftiti, Z. (2021). ICT diffusion and economic growth: Evidence from the sectorial analysis of a periphery country. *Technological Forecasting and Social Change*, *162*, 120403. https://doi.org/10.1016/j.techfore.2020.120403

Kathuria, V., & Oh, K. Y. (2018). ICT access: Testing for convergence across countries. *The Information Society*, *34*(3), 166–182. https://doi.org/10.1080/01972243.2018.1438549

Khan, F. N., Sana, A., & Arif, U. (2020). Information and communication technology (ICT) and environmental sustainability: A panel data analysis. *Environmental Science and Pollution Research*, *27*(29), 36718–36731. https://doi.org/10.1007/s11356-020-09704-1

Koski, H. A., & Majumdar, S. K. (2000). Convergence in telecommunications infrastructure development in OECD countries. *Information Economics and Policy*, *12*(2), 111–131. https://doi.org/10.1016/S0167-6245(00)00003-2

Kot, S., & Ojinji, S. (2023). Environmental Sustainability and Freight Transport Performance in the EU–An Autoregressive Conditional Heteroscedasticity (ARCH) Model Analysis. *Promet-Traffic&Transportation*, 35(5), 621-634. https://doi.org/10.7307/ptt.v35i5.293

Lee, S., Nam, Y., Lee, S., & Son, H. (2016). Determinants of ICT innovations: A cross-country empirical study. *Technological Forecasting and Social Change*, *110*, 71–77. https://doi.org/10.1016/j.techfore.2015.11.010

Maciulyte-Sniukiene, A., & Butkus, M. (2022). Does Infrastructure Development Contribute to EU Countries' Economic Growth? *Sustainability*, *14*(9), 5610. https://doi.org/10.3390/su14095610

Mačiulytė-Šniukienė, A., Butkus, M., & Davidavičienė, V. (2022). Development of the model to examine the impact of infrastructure on economic growth and convergence. *Journal of Business Economics and Management*, *23*(3), Article 3. https://doi.org/10.3846/jbem.2022.17140

Mačiulytė-Šniukienė, A., Butkus, M., & Szarucki, M. (2022). Infrastructure in the framework of production functions: evidence of eu member states at the regional level. *Technological and Economic Development of Economy*, *28*(6), 1871–1879. https://doi.org/10.3846/tede.2022.18090

Maparu, T. S., & Mazumder, T. N. (2021). Investigating causality between transport infrastructure and urbanization: A state-level study of India (1991–2011). *Transport Policy*, *113*, 46–55. https://doi.org/10.1016/j.tranpol.2020.03.008

Meersman, H., & Nazemzadeh, M. (2017). The contribution of transport infrastructure to economic activity: The case of Belgium. *Case Studies on Transport Policy*, *5*(2), 316–324. https://doi.org/10.1016/j.cstp.2017.03.009

Misuraca, G., & Pasi, G. (2021). Shaping the Welfare Society: Unleashing Transformation Through ICT-Enabled Social Innovation. In Perspectives for Digital Social Innovation to Reshape the European Welfare System. In F. Davide, A. Gaggioli, & G. Misuraca (Eds.), *Perspectives for Digital Social Innovation to Reshape the European Welfare System*. IOS Press.

Nair, M., Pradhan, R. P., & Arvin, M. B. (2020). Endogenous dynamics between R&D, ICT and economic growth: Empirical evidence from the OECD countries. *Technology in Society*, *62*, 101315. https://doi.org/10.1016/j.techsoc.2020.101315

Pandya, F., & Maind, S. (2017). Panel data analysis: Convergence of Indian states with infrastructure. *Journal of Social and Economic Development*, *19*(1), 181–195. https://doi.org/10.1007/s40847-017-0033-3

Park, S. R., Choi, D. Y., & Hong, P. (2015). Club convergence and factors of digital divide across countries. *Technological Forecasting and Social Change*, *96*, 92–100. https://doi.org/10.1016/j.techfore.2015.02.011

Pasha, O., Wyczalkowski, C., Sohrabian, D., & Lendel, I. (2020). Transit effects on poverty, employment, and rent in Cuyahoga County, Ohio. *Transport Policy*, *88*, 33–41. https://doi.org/10.1016/j.tranpol.2020.01.013

Potere, D., & Schneider, A. (2007). A critical look at representations of urban areas in global maps. *GeoJournal*, *69*(1–2), 55–80. https://doi.org/10.1007/s10708-007-9102-z

Pradhan, R. P. (2019). Investigating the causal relationship between transportation infrastructure, financial penetration and economic growth in G-20 countries. *Research in Transportation Economics*, *78*, 100766. https://doi.org/10.1016/j.retrec.2019.100766

Pradhan, R. P., Arvin, M. B., & Nair, M. (2021). Urbanization, transportation infrastructure, ICT, and economic growth: A temporal causal analysis. *Cities*, *115*, 103213. https://doi.org/10.1016/j.cities.2021.103213

Rath, B. N., Panda, B., & Akram, V. (2023). Convergence and determinants of ICT development in case of emerging market economies. *Telecommunications Policy*, *47*(2), 102464. https://doi.org/10.1016/j.telpol.2022.102464

Roger, M., Shulin, L., & Sesay, B. (2022). ICT Development, Innovation Diffusion and Sustainable Growth in Sub-Saharan Africa. *SAGE Open*, *12*(4), 215824402211238. https://doi.org/10.1177/21582440221123894

Saba, C. S. (2021). Convergence and transition paths in transportation: Fresh insights from a club clustering algorithm. *Transport Policy*, *112*, 80–93. https://doi.org/10.1016/j.tranpol.2021.08.008

Saba, C. S., & David, O. O. (2020). Convergence patterns in global ICT: Fresh insights from a club clustering algorithm. *Telecommunications Policy*, *44*(10), 102010. https://doi.org/10.1016/j.telpol.2020.102010

Saba, C. S., & David, O. O. (2022). Identifying Convergence in Telecommunication Infrastructures and the Dynamics of Their Influencing Factors Across Countries. *Journal of the Knowledge Economy*. https://doi.org/10.1007/s13132-022-00967-2

Saba, C. S., Ngepah, N., & Odhiambo, N. M. (2021). Analysis of convergence in transport infrastructure: A global evidence. *European Journal of Transport and Infrastructure Research*, 137-160 Pages. https://doi.org/10.18757/EJTIR.2021.21.2.5368

Samir, S., & Mefteh, H. (2020). Empirical Analysis of the Dynamic Relationships between Transport, ICT and FDI in 63 Countries. *International Economic Journal*, *34*(3), 448–471. https://doi.org/10.1080/10168737.2020.1765186

Sarania, R. (2021). Interactions among Infrastructure, Trade Openness, Foreign Direct Investments and Economic Growth in India. *Journal of Infrastructure Development*, *13*(1), 21–43. https://doi.org/10.1177/09749306211023621

Sawng, Y., Kim, P., & Park, J. (2021). ICT investment and GDP growth: Causality analysis for the case of Korea. *Telecommunications Policy*, *45*(7), 102157. https://doi.org/10.1016/j.telpol.2021.102157

United Nations. (2011). *World Urbanization Prospects The 2011 Revision*. Department of Economic and Social Affairs, Population Division: United Nations.

Wang, C., Lim, M. K., Zhang, X., Zhao, L., & Lee, P. T.-W. (2020). Railway and road infrastructure in the Belt and Road Initiative countries: Estimating the impact of transport infrastructure on economic growth. *Transportation Research Part A: Policy and Practice*, *134*, 288–307. https://doi.org/10.1016/j.tra.2020.02.009

Wang, N., Zhu, Y., & Yang, T. (2020). The impact of transportation infrastructure and industrial agglomeration on energy efficiency: Evidence from China's industrial sectors. *Journal of Cleaner Production*, *244*, 118708. https://doi.org/10.1016/j.jclepro.2019.118708

Xu, Y., & Yang, X. (2021). Access to ports and the welfare gains from domestic transportation infrastructure. *Journal of Urban Economics*, *126*, 103392. https://doi.org/10.1016/j.jue.2021.103392

Zhang, A., Wan, Y., & Yang, H. (2019). Impacts of high-speed rail on airlines, airports and regional economies: A survey of recent research. *Transport Policy*, *81*, A1–A19. https://doi.org/10.1016/j.tranpol.2019.06.010

Zhang, F., & Graham, D. J. (2020). Air transport and economic growth: a review of the impact mechanism and causal relationships. *Transport Revviews, 40* (4), 506–528, https://doi.org/10.1080/01441647.2020.1738587

APPENDICES

Table A

Transport infrastructure convergence among EU Member states during the period 2000–2019

	2000–2019					
	MOT_1	**MOT_2**	**MOT_3**	**MOT_4**	**MOT_5**	**MOT_6**
β	−0.016**	−0.016***	−0.016***	−0.029***	−0.017***	−0.016***
	(0.007)	(0.005)	(0.005)	(0.006)	(0.005)	(0.005)
	Ln_Y	**IQ (1)**	**IQ (2)**	**Ln_POP**	**OPEN**	**FDI**
γ	−0.002	−0.002	−0.003	0.025***	0.0001	0.000
	(0.014)	(0.007)	(0.013)	(0.007)	(0.000)	(0.000)
Obs.	22	22	22	22	22	22
	RLW_1	**RLW_2**	**RLW_3**	**RLW_4**	**RLW_5**	**RLW_6**
β	−0.002	−0.001	−0.001	−0.004	−0.002	−0.002
	(0.002)	(0.003)	(0.002)	(0.004)	(0.003)	(0.006)
	Ln_Y	**IQ (1)**	**IQ (2)**	**Ln_POP**	**OPEN**	**FDI**
γ	0.001	−0.002	−0.004	0.002	0.000	–0.000
	(0.001)	(0.003)	(0.004)	(0.003)	(0.000)	(0.000)
Obs.	23	23	23	23	23	23
	AIR_1	**AIR_2**	**AIR_3**	**AIR_4**	**AIR_5**	**AIR_6**
β	−0.011*	−0.011	−0.011*	−0.010	−0.012*	−0.010*
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.005)
	Ln_Y	**IQ (1)**	**IQ (2)**	**Ln_POP**	**OPEN**	**FDI**
γ	−0.007	0.004	0.008	–0.000	−0.000	−0.000
	(0.013)	(0.009)	(0.016)	(0.006)	(0.000)	(0.000)
Obs.	10	10	10	10	10	10

Note. The table represents estimation results of conditional β-convergence. Heterostedasticity robust standard errors are represented in parentheses. *, **, *** indicate significance at the 10, 5, and 1 percent level, respectively.

Table B

Transport infrastructure convergence among EU Member states during the period 2000–2006

	2000–2006					
	MOT_1	**MOT_2**	**MOT_3**	**MOT_4**	**MOT_5**	**MOT_6**
β	−0.009	−0.013	−0.014	−0.033***	−0.014	−0.015
	(0.011)	(0.009)	(0.009)	(0.009)	(0.009)	(0.010)
	Ln_Y	**IQ (1)**	**IQ (2)**	**Ln_POP**	**OPEN**	**FDI**
γ	−0.014	−0.009	−0.009	0.041***	0.000	0.001
	(0.026)	(0.015)	(0.030)	(0.013)	(0.000)	(0.001)
Obs.	22	22	22	22	22	22
	RLW_1	**RLW_2**	**RLW_3**	**RLW_4**	**RLW_5**	**RLW_6**
β	−0.003	−0.003	−0.003	−0.005	−0.004	−0.004
	(0.004)	(0.003)	(0.003)	(0.006)	(0.004)	(0.004)
	Ln_Y	**IQ (1)**	**IQ (2)**	**Ln_POP**	**OPEN**	**FDI**
γ	0.001	−0.001	−0.002	0.002	0.000	0.000
	(0.002)	(0.003)	(0.005)	(0.003)	(0.000)	(0.000)
Obs.	23	23	23	23	23	23
	AIR_1	**AIR_2**	**AIR_3**	**AIR_4**	**AIR_5**	**AIR_6**
β	−0.018	−0.026	−0.028	−0.017	−0.023	−0.023
	(0.018)	(0.018)	(0.019)	(0.023)	(0.022)	(0.019)
	Ln_Y	**IQ (1)**	**IQ (2)**	**Ln_POP**	**OPEN**	**FDI**
γ	0.034	0.039	0.068	−0.008	−0.000	−0.002
	(0.029)	(0.023)	(0.039)	(0.019)	(0.000)	(0.002)
Obs.	10	10	10	10	10	10

Note. The table represents estimation results of conditional β-convergence. Heterostedasticity robust standard errors are represented in parentheses. *, **, *** indicate significance at the 10, 5, and 1 percent level, respectively.

Table C

Transport infrastructure convergence among EU Member states during the period 2007–2013

	2007–2013					
	MOT_1	**MOT_2**	**MOT_3**	**MOT_4**	**MOT_5**	**MOT6**
β	−0.034***	−0.032***	−0.032***	−0.049***	−0.033***	−0.032***
	(0.012)	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)
	Ln_Y	**IQ (1)**	**IQ (2)**	**Ln_POP**	**OPEN**	**FDI**
γ	0.007	−0.002	0.003	0.037***	0.000	0.000
	(0.020)	(0.011)	(0.023)	(0.010)	(0.000)	(0.000)
Obs.	24	24	24	24	24	24
	RLW_1	**RLW_2**	**RLW_3**	**RLW_4**	**RLW_5**	**RLW_6**
β	−0.001	0.000	0.001	−0.004	−0.002	−0.002
	(0.005)	(0.006)	(0.006)	(0.011)	(0.005)	(0.005)
	Ln_Y	**IQ (1)**	**IQ (2)**	**Ln_POP**	**OPEN**	**FDI**
γ	0.003	−0.002	−0.007	0.004	0.000	0.001***
	(0.003)	(0.005)	(0.012)	(0.008)	(0.000)	(0.000)
Obs.	24	24	24	24	24	24
	AIR_1	**AIR_2**	**AIR_3**	**AIR_4**	**AIR_5**	**AIR_6**
β	−0.003	−0.003	−0.003	−0.003	−0.004	−0.003
	(0.005)	(0.005)	(0.005)	(0.005)	(0.007)	(0.005)
	Ln_Y	**IQ (1)**	**IQ (2)**	**Ln_POP**	**OPEN**	**FDI**
γ	−0.004	−0.011	−0.018	0.002	−0.000	0.000
	(0.009)	(0.008)	(0.018)	(0.005)	(0.000)	(0.000)
Obs.	26	26	26	26	26	26

Note. The table represents estimation results of conditional β-convergence. Heterostedasticity robust standard errors are represented in parentheses. *, **, *** indicate significance at the 10, 5, and 1 percent level, respectively.

Table D

Transport infrastructure convergence among EU Member states during the period 2014–2019

2014–2019						
	MOT_1	**MOT_2**	**MOT_3**	**MOT_4**	**MOT_5**	**MOT_6**
β	−0.009	−0.011**	−0.011**	−0.022**	−0.013***	−0.011**
	(0.005)	(0.005)	(0.005)	(0.011)	(0.004)	(0.005)
	Ln_Y	**IQ (1)**	**IQ (2)**	**Ln_POP**	**OPEN**	**FDI**
γ	−0.007	0.005	0.000	0.018	0.0001**	0.000
	(0.007)	(0.014)	(0.019)	(0.013)	(0.000)	(0.000)
Obs.	24	24	24	24	24	24
	RLW_1	**RLW_2**	**RLW_3**	**RLW_4**	**RLW_5**	**RLW_6**
β	−0.002	−0.002	−0.002	−0.005*	−0.004	−0.003
	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)
	Ln_Y	**IQ (1)**	**IQ (2)**	**Ln_POP**	**OPEN**	**FDI**
γ	−0.001	−0.002	−0.003	0.002	0.000	0.000
	(0.002)	(0.002)	(0.003)	(0.002)	(0.000)	(0.000)
Obs.	24	24	24	24	24	24
	AIR_1	**AIR_2**	**AIR_3**	**AIR_4**	**AIR_5**	**AIR_6**
β	−0.009*	−0.012***	−0.012***	−0.013 ***	−0.012**	−0.012***
	(0.004)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)
	Ln_Y	**IQ (1)**	**IQ (2)**	**Ln_POP**	**OPEN**	**FDI**
γ	−0.022*	−0.015*	−0.024	0.003	0.000	−0.000
	(0.012)	(0.008)	(0.015)	(0.004)	(0.000)	(0.000)
Obs.	27	27	27	27	27	27

Note. The table represents estimation results of conditional β-convergence. Heterostedasticity robust standard errors are represented in parentheses. *, **, *** indicate significance at the 10, 5, and 1 percent level, respectively.

Table E

Transport infrastructure convergence among NUTS 2 regions during the different periods of EU Structural Funds financial support and the whole period

	2000–2006			2007–2013			2014–2019			2000–2019		
	MOT$_1$	**MOT$_2$**	**MOT$_3$**	**MOT$_1$**	**MOT$_2$**	**MOT$_3$**	**MOT$_1$**	**MOT$_2$**	**MOT$_3$**	**MOT$_1$**	**MOT$_2$**	**MOT$_3$**
β	−0.007	−0.015***	−0.025***	−0.009	−0.015**	−0.025***	−0.012**	−0.011***	−0.030***	−0.007**	−0.006**	−0.022***
	(0.005)	(0.005)	(0.009)	(0.008)	(0.007)	(0.009)	(0.005)	(0.004)	(0.009)	(0.003)	(0.003)	(0.003)
	Ln_Y	**IQ**	**Ln_POP**	**Ln_Y**	**IQ**	**Ln_POP**	**Ln_Y**	**IQ**	**Ln_POP**	**Ln_Y**	**IQ**	**Ln_POP**
γ	−0.035***	−0.007	0.015*	−0.020**	−0.006	0.013**	−0.008	−0.011**	0.021**	−0.016***	−0.017***	0.015***
	(0.010)	(0.008)	(0.008)	(0.009)	(0.004)	(0.006)	(0.007)	(0.004)	(0.010)	(0.005)	(0.004)	(0.003)
Obs.	130	120	110	145	135	126	100	90	100	74	64	74
	RLW$_1$	**RLW$_2$**	**RLW$_3$**	**RLW$_1$**	**RLW$_2$**	**RLW$_3$**	**RLW$_1$**	**RLW$_2$**	**RLW$_3$**	**RLW$_1$**	**RLW$_2$**	**RLW$_3$**
β	−0.002	−0.003	−0.014***	−0.004	−0.004	−0.016*	−0.002	−0.001	0.001	0.001	0.001	−0.003
	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)	(0.009)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)
	Ln_Y	**IQ**	**Ln_POP**	**Ln_Y**	**IQ**	**Ln_POP**	**Ln_Y**	**IQ**	**Ln_POP**	**Ln_Y**	**IQ**	**Ln_POP**
γ	0.012***	0.005*	0.011**	0.007***	0.005***	0.010**	−0.005**	−0.006**	−0.003	0.004***	0.002	0.004
	(0.004)	(0.003)	(0.004)	(0.002)	(0.002)	(0.004)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
Obs.	84	84	84	128	128	128	113	113	113	69	69	69
	AIR$_1$	**AIR$_2$**	**AIR$_3$**	**AIR$_1$**	**AIR$_2$**	**AIR$_3$**	**AIR$_1$**	**AIR$_2$**	**AIR$_3$**	**AIR$_1$**	**AIR$_2$**	**AIR$_3$**
β	−0.021***	−0.023***	−0.021***	−0.008	−0.008	−0.004	0.007*	0.006	0.002	0.001	0.002	−0.000
	(0.007)	(0.008)	(0.007)	(0.007)	(0.007)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
	Ln_Y	**IQ**	**Ln_POP**	**Ln_Y**	**IQ**	**Ln_POP**	**Ln_Y**	**IQ**	**Ln_POP**	**Ln_Y**	**IQ**	**Ln_POP**
γ	−0.013	−0.019	−0.003	−0.001	−0.006	0.009*	−0.035***	−0.020***	0.003	−0.001	0.002	0.004
	(0.030)	(0.018)	(0.008)	(0.013)	(0.005)	(0.005)	(0.010)	(0.005)	(0.004)	(0.010)	(0.006)	(0.003)
Obs.	73	61	56	157	135	130	166	144	136	84	72	67

Note. The table represents estimation results of conditional β-convergence. Heterostedasticity robust standard errors are represented in parentheses. *, **, *** indicate significance at the 10, 5, and 1 percent level, respectively.

Table F

ICT infrastructure convergence among EU Member states during different periods of EU Structural Funds financial support and the whole period

	2007–2019							
	INT_1	**INT_2**	**INT_3**	**INT_4**	**INT_5**	**INT_6**	**INT_7**	**INT_8**
β	−0.075***	−0.073***	−0.071***	−0.071***	−0.071***	−0.072***	−0.070***	−0.070***
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
	Ln_Y	**R&D**	**IQ (1)**	**IQ (2)**	**Ln_POP**	**EDU**	**OPEN**	**FDI**
γ	0.003**	0.001	0.000	0.001	–0.000	0.000	–0.000	0.00004***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.000)	(0.000)	(0.000)
Obs.	27	27	27	27	27	27	27	27
	BRD_1	**BRD_2**	**BRD_3**	**BRD_4**	**BRD_5**	**BRD_6**	**BRD_7**	**BRD_8**
β	−0.079***	−0.078***	−0.077***	−0.076***	−0.076***	−0.078***	−0.076***	−0.076***
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
	Ln_Y	**R&D**	**IQ (1)**	**IQ (2)**	**Ln_POP**	**EDU**	**OPEN**	**FDI**
γ	0.004***	0.001*	0.001	0.002	0.000	0.0002**	0.000	0.0001***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.000)	(0.000)	(0.000)
Obs.	27	27	27	27	27	27	27	27
	2007–2013							
	INT_1	**INT_2**	**INT_3**	**INT_4**	**INT_5**	**INT_6**	**INT_7**	**INT_8**
β	−0.105***	−0.105***	−0.101***	−0.100***	−0.099***	−0.100***	−0.101***	−0.099***
	(0.007)	(0.007)	(0.005)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)
	Ln_Y	**R&D**	**IQ (1)**	**IQ (2)**	**Ln_POP**	**EDU**	**OPEN**	**FDI**
γ	0.004	0.003	0.003	0.003	0.001	0.000	0.000	−0.000
	(0.004)	(0.002)	(0.003)	(0.006)	(0.001)	(0.000)	(0.000)	(0.000)
Obs.	27	27	27	27	27	27	27	27
	BRD_1	**BRD_2**	**BRD_3**	**BRD_4**	**BRD_5**	**BRD_6**	**BRD_7**	**BRD_8**
β	−0.134***	−0.140***	−0.133***	−0.132***	−0.132***	−0.130***	−0.130***	−0.131***
	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)
	Ln_Y	**R&D**	**IQ (1)**	**IQ (2)**	**Ln_POP**	**EDU**	**OPEN**	**FDI**
γ	0.003	0.008***	0.007**	0.012*	0.001	−0.000	−0.000	0.000
	(0.005)	(0.003)	(0.003)	(0.006)	(0.002)	(0.000)	(0.000)	(0.000)
Obs.	26	26	26	26	26	26	26	26
	2014–2019							
	INT_1	**INT_2**	**INT_3**	**INT_4**	**INT_5**	**INT_6**	**INT_7**	**INT_8**
β	−0.129***	−0.119***	−0.114***	−0.114***	−0.112***	−0.121***	−0.109***	−0.111***
	(0.017)	(0.010)	(0.009)	(0.009)	(0.009)	(0.012)	(0.008)	(0.008)
	Ln_Y	**R&D**	**IQ (1)**	**IQ (2)**	**Ln_POP**	**EDU**	**OPEN**	**FDI**
γ	0.004	0.001	0.001	0.001	−0.001	0.000	–0.00002**	0.0001***
	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)	(0.000)	(0.000)	(0.000)
Obs.	27	27	27	27	27	27	27	27
	BRD_1	**BRD_2**	**BRD_3**	**BRD_4**	**BRD_5**	**BRD_6**	**BRD_7**	**BRD_8**
β	−0.126***	−0.114***	−0.111***	−0.111***	−0.109***	−0.120***	−0.107***	−0.109***
	(0.020)	(0.012)	(0.011)	(0.010)	(0.010)	(0.013)	(0.010)	(0.010)
	Ln_Y	**R&D**	**IQ (1)**	**IQ (2)**	**Ln_POP**	**EDU**	**OPEN**	**FDI**
γ	0.004	0.001	0.001	0.002	−0.001	−0.001	−0.000	0.0001***
	(0.003)	(0.002)	(0.002)	(0.003)	(0.001)	(0.001)	(0.000)	(0.000)
Obs.	27	27	27	27	27	27	27	27

Note. The table represents estimation results of conditional β-convergence. Heterostedasticity robust standard errors are represented in parentheses. *, **, *** indicate significance at the 10, 5, and 1 percent level, respectively.

Table G

ICT infrastructure convergence among NUTS 2 regions during the different periods of EU Structural Funds financial support and the whole period

	2007–2013					2014–2019					2007–2019				
	INT_1	**INT_2**	**INT_3**	**INT_4**	**INT_5**	**INT_1**	**INT_2**	**INT_3**	**INT_4**	**INT_5**	**INT_1**	**INT_2**	**INT_3**	**INT_4**	**INT_5**
β	−0.093***	−0.102***	−0.106***	−0.098***	−0.100***	−0.135***	−0.119***	−0.139***	−0.117***	−0.131***	−0.070***	−0.070***	−0.075***	−0.070***	−0.074***
	(0.005)	(0.005)	(0.006)	(0.004)	(0.004)	(0.007)	(0.006)	(0.008)	(0.005)	(0.006)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)
	Ln_Y	**R&D**	**IQ**	**Ln_POP**	**EDU**	**Ln_Y**	**R&D**	**IQ**	**Ln_POP**	**EDU**	**Ln_Y**	**R&D**	**IQ**	**Ln_POP**	**EDU**
γ	−0.004	0.004***	0.005**	0.001	0.000	0.005***	−0.000	0.004***	−0.001*	0.0003***	0.000	–0.000	0.003***	0.000	0.0003***
	(0.006)	(0.005)	(0.002)	(0.001)	(0.000)	(0.002)	(0.001)	(0.001)	(0.000)	(0.000)	(0.002)	(0.001)	(0.001)	(0.000)	(0.000)
Obs	75	75	73	75	75	155	122	143	135	155	75	75	73	75	75
	BRD_1	**BRD_2**	**BRD_3**	**BRD_4**	**BRD_5**	**BRD_1**	**BRD_2**	**BRD_3**	**BRD_4**	**BRD_5**	**BRD_1**	**BRD_2**	**BRD_3**	**BRD_4**	**BRD_5**
β	−0.136***	−0.131***	−0.129***	−0.126***	−0.122***	−0.120***	−0.117***	−0.120***	−0.114***	−0.127***	0.073***	−0.072***	−0.073***	−0.072***	−0.074***
	(0.003)	(0.003)	(0.005)	(0.003)	(0.003)	(0.008)	(0.007)	(0.009)	(0.005)	(0.007)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
	Ln_Y	**R&D**	**IQ**	**Ln_POP**	**EDU**	**Ln_Y**	**R&D**	**IQ**	**Ln_POP**	**EDU**	**Ln_Y**	**R&D**	**IQ**	**Ln_POP**	**EDU**
γ	0.020***	0.006***	0.003	0.000	−0.000	0.001	−0.001	0.001	−0.001**	0.000	0.002	−0.000	0.001	0.000	0.000
	(0.005)	(0.002)	(0.002)	(0.002)	(0.000)	(0.002)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)
Obs	75	75	73	75	75	155	122	143	135	155	75	75	73	75	75

Note. The table represents estimation results of conditional β-convergence. Heterostedasticity robust standard errors are represented in parentheses. *, **, *** indicate significance at the 10, 5, and 1 percent level, respectively.