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Article

Convergence of EU countries according to economic complexity

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Abstract: The economic complexity approach presents a shift from quantitative to qualitative measures of economic performance, while economic complexity refers to the accumulation of know-how. Economic complexity is considered a predictor of economic growth and research evidences a positive relationship between economic complexity and economic growth. In the EU countries, economic convergence is observed. Hence the question of economic complexity convergence arises, too. The paper aims to analyze the convergence of 27 EU countries considering their economic complexity from 1999 to 2021 computing the beta convergence. Using the Barro-type regressions, the econometric estimations focus on four indices of economic complexity—the economic complexity index published by Harvard's Growth Lab, and economic complexity indices on research, trade, and technology published by the Observatory of Economic Complexity. The absolute beta convergence is observed in the EU except for the economic complexity index referring to trade. When including the dummy referring to the location of EU countries in the West or East of the EU considering their wealth, the conditional beta convergence is observed except for the trade-economic complexity index, again. When altering the condition of location by the GDP per capita and other controls, the conditional beta convergence of economic complexity in the EU is observed when estimating both fixed-effect models and dynamic panel data models based on the system generalized method of moments (GMM) estimator.

Keywords: economic complexity; economic complexity index; beta convergence; European Union

1. Introduction

Economic complexity is a measure of the knowledge in society (The Atlas of Economic Complexity and Harvard's Growth Lab, 2023), that is considered a moving force for long-run economic growth (Balland and Rigby, 2017). The economic complexity approach presents a shift from thinking in quantitative measures based on expressing how much a country makes (expressed e.g., in GDP terms) to thinking about what a country makes (Pugliese and Tacchell, 2021). The empirical evidence observes an obvious relationship between economic complexity and economic growth. According to Pinheiro et al. (2022) evolving economies are more complex. They tend to accumulate know-how (Hausmann et al., 2011; Hausmann et al., 2014), which contributes to economic development (Hausmann et al., 2011; Hausmann et al., 2014; Özgüzer and Oğuş-Binatlı, 2016; etc.). For measuring the economic complexity of a country, Hidalgo and Hausmann (2009) introduced the Economic Complexity Index (ECI). It ranks countries according to the diversity and complexity of their export baskets. According to Schetter (2021), the ECI mirrors the countries' economic strength and future growth prospects. Countries with higher ECI tend to reach higher income levels (Özgüzer and Oğuş-Binatlı, 2016).

Economic growth and convergence are under scrutiny in the array of scientific literature, (Strielkowski and Höschle, 2013; Chapsa et al., 2015; Özgüzer and Oğuş-Binatlı, 2016; etc.). In the EU conditions, the accession of new member states stared up an extensive discussion (Strielkowski and Höschle, 2016; Özgüzer and Oğuş-Binatlı, 2016; Cieślik and Wciślik, 2020) when both economic growth and convergence present a focal point. Economic convergence became important with movements toward economic integration (Monfort et al., 2013; Cieślik and Wciślik, 2020) and new member states are constantly compared to the rest of the EU countries (Cieślik and Wciślik, 2020).

The paper aims to examine the convergence of 27 EU countries considering their economic complexity from 1999 to 2021. The motivation arises from the idea mentioned by Pugliese and Tacchell (2021), considering the economic complexity approach as a shift in thinking about the countries' economic outcomes toward their economic activities, while the knowledge of the society is encountered, too (Balland and Rigby, 2017). Based on an assumption that the economic complexity emulates and predicts the economic development of the country (Özgüzer and Oğuş-Binatlı, 2016), we alter the standard measure of economic growth (the GDP per capita, e.g., Strielkowski and Höschle, 2016; Cieślik and Wciślik, 2020; Pugliese and Tacchell, 2021; etc.) with the economic complexity measures when computing the absolute and conditional beta convergence of the EU countries. As the empirical evidence observes a positive relationship between economic complexity and economic growth (Pinheiro et al., 2022.; Le et al., 2022; Mao and An, 2021; etc.), we employ the economic complexity indices (Hidalgo and Hausmann, 2009) for the sample of 27 EU countries in 1999–2021 to capture the convergence processes inside the EU. The beta convergence is computed following the contribution of Barro and Sala-i-Martin (1992).

2. Review of literature

When comparing the economic strength of countries and their economic development over time, the approach of convergence is frequently employed. As mentioned by Strielkowski and Höschle (2016), the convergence signalizes that the difference between two or more variables over time decreases and becomes negligible. According to Cieślik and Wciślik (2020), the convergence implies the equalization of growth rates. In the recent scientific literature, the empirical testing of economic convergence moved from the concept of sigma convergence to beta convergence. While the first mentioned assumes that dispersion of the variable values decreases over time (Sala-i-Martin, 1996), beta convergence implies a decline of dispersion because poor regions have stronger economic growth than rich regions (Sala-i-Martin, 1996; Capello and Nijkamp, 2009, Goecke and Huether, 2016). For this reason, a plethora of authors, e.g., Strielkowski and Höschle (2016), Monfort et al. (2013), Beyaert and García-Solanes (2014), etc. divide the sample of EU countries into several groups according to their wealth. The conditional beta convergence captures the region-related issues pointing to different starting points of countries in terms of economic development (Allington and McCombie, 2007; Chapsa et al., 2015; Goecke and Huether, 2016; Nagy and Šiljak, 2022). If there are no conditioning variables, the absolute beta convergence is computed (Allington and McCombie, 2007).

In the empirical literature on economic convergence within the EU, certain doubts could be found, because of its extensive heterogeneity. Monfort, Cuestas and Ordóñez (2013) state, that there is an obvious difference between the wealth of new and old EU member states. According to them, the real convergence within the EU was supported by the fact, that all new member states are transitive economies and they belong to the common European market. Rapacki and Próchniak (2019) mention, that new EU member states had access to EU funds which enhanced the convergence, too. Strielkowski and Höschle (2016) divide EU countries into clusters according to their accession to the EU and investigate, whether these clusters converge against each other. Their findings weakly support the assumption of economic convergence within the EU. Contrary, an earlier study by Matkowski and Próchniak (2007) finds evidence of real economic convergence within the EU. Vojinović et al. (2010) find evidence for both sigma and beta convergence within the EU members observing the acceleration of the beta convergence near the EU accession period. Their results support the idea of beta convergence when they mention that new and poorer EU members grow faster than the new and richer ones. Besides, they state, that the income gap decreases, but is still large. The economic convergence in the EU was observed by many authors using different estimation techniques following the Barro-type regression (Barro and Sala-i-Martin, 1992), e.g., Chapsa et al. (2015) use a system GMM estimator, Colak (2015) uses the fixed-effect models (FEM), Rapacki and Próchniak (2019) use the fixed-effect and random-effect models (REM) and system GMM estimator, Díaz-Dapena et al. (2019) use the Durbin model considering spatial effects. Nagy and Šiljak use an ordinary least square (OLS) regression to compute the sigma and beta convergence of EU countries. They divided the period 2004–2018 into three sub-periods ending with 2008, 2014, and 2018 to absorb short-term disturbances that may occur (the process proposed by Islam, 1995). Their findings are about to support empirically the economic convergence in the EU, too.

It is evidenced that EU countries converge in terms of economic growth. The economic complexity mirroring the accumulation of knowledge contributing to economic growth (Balland and Rigby, 2017) could express the level of the economic development of the country, too (Schetter, 2021; Özgüzer and Oğuş-Binatlı, 2016). Based on the literature on economic complexity we consider economic complexity as an alternative measure of economic growth as mentioned hereinafter. We expect to observe a process of convergence in economic complexity for several reasons. New EU members by the EU accession started to draw EU funds to decrease regional disparities and increase economic growth. Besides, they have joined the common EU market (Monfort et al., 2013) with low labor and production cost, and lower tax rates fostering horizontal tax competition (Horváth et al., 2013). By attracting the mobile capital, their economic complexity increased dramatically in the first half of the monitored period, when compared to the economic complexity indicators of old EU members (based on group means of economic complexity indicators for new and old member states, data provided by Harvard's Growth Lab, 2023; Observatory of Economic Complexity, 2023).

The empirical literature on beta convergence of EU countries focuses on several factors, that determine the process of economic convergence inside the EU. Beyaert and García-Solanes (2014) consider the effect of the global financial crisis (GFC), while Pina and Sicari (2021) mention, that the divergence has been evidenced in the

EU after the GFC. Contrary, Nagy and Šiljak (2022) mention, that the GFC caused the divergence processes within the EU countries only in the case of absolute beta convergence. Chapsa et al. (2015), like many other authors, employ beta convergence introduced by Barro and Sala-i-Martin (1992) to measure the economic convergence in the EU, and control for factors such as investment in physical and human capital, inflation, government consumption and openness, corruption, and bureaucracy. Using a system-GMM to avoid the endogeneity problem. Nagy and Šiljak (2022) control for economic openness, inflation, government integrity, and unemployment.

The examination of the relationship between economic convergence and economic complexity is provided by Özgüzer and Oğuş-Binatlı (2016). They investigate income level convergence in EU countries according to their economic complexity. The contribution of the higher economic complexity to lowering the income inequalities, which determine economic development, is examined e.g., by Hartmann et al. (2017) and Fawaz and Rahnama-Moghadamm (2019). They found out, that countries with higher ECI enjoy lower levels of income inequality.

A branch of empirical studies investigates the relationship between the economic complexity and various economic categories mirroring the economic development and economic conditions of the countries in question. Mao and An (2021) examine the relationship between the economic complexity measured using the ECI and the level of development in a sample of 57 middle and high-income countries from 1995 to 2010. They focus on OLS, FEM, and system GMM estimations finding a positive influence of ECI on GDP per capita controlling for investments, openness, human capital (expecting positive effect as mentioned in Barro and Lee, 1994), population (influences GDP per capita because it is expressed in per capita terms), and government consumption, similarly to Chapsa et al. (2015). Zhu and Li (2016) investigate the impact of economic complexity and human capital on economic growth. Khan et al. (2020) confirm the relationship between economic complexity and Foreign direct investments. They include additional control variables such as institutional quality, information and communication technology, trade openness, per capita GDP, domestic investment, and human capital. Adam et al. (2023) show, that the economic complexity positively influences the employment rate.

Another array of empirical literature focuses on determinants of economic complexity. Pinheiro et al. (2022) mention that higher economic complexity is related to economically advanced regions. The effect on economic complexity is measured using the GDP per capita and population density. Mao and An (2021) investigate the ECI determinants employing the variable expressing the global value chains, export, import, inflow foreign direct investments (FDI), outflow FDI, real GDP, research and development (R&D), and human capital. Soyyiğit and Michalski (2022) search determinants of ECI in a V4 group considering the effect of FDI, the logarithm of expenditure on R&D, and number of researchers per 1000 employed. Yalta and Yalta (2021) investigate determinants of economic complexity in the Middle East and North Africa (MENA) countries using the GMM and considering factors such as trade, investments, natural resource rent, GDP per capita, FDI, and average years of schooling (primary, secondary, and tertiary education). Avom and Ndoya (2022) examine the relationship between economic stability and economic complexity using the system GMM and they find the positive effect.

3. Methodology

In this paper, the economic complexity index (ECI) alters the traditional measure of convergence, the GDP per capita. Besides the ECI provided by Harvard's Growth Lab (2023), to provide a complex view of the EU countries' convergence in terms of their economic complexity mirroring their economic development and economic strength, we employ further measures of economic complexity, ECI trade, ECI technology, and ECI research, that are discussed in Simoes and Hidalgo (2011) available at Observatory of Economic Complexity, provided by the Massachusetts Institute of Technology (MIT). We proceed in the manner promoted by Barro and Sala-i-Martin (1992) when computing absolute and conditional beta convergence. As mentioned hereinafter, this manner is widely used in convergence literature (Chapsa et al., 2015; Colak, 2015; Rapacki and Próchniak, 2019; etc.).

In this research, the existence of beta convergence is examined using econometric modeling. Our sample consists of 27 EU members. The considered period is 1999–2021 due to the data availability. The ECI variables present a left-side of econometric equations when considering four types of dependent variables (see. **Table 1**)—ECI, ECI research, ECI trade, and ECI technology (Harvard's Growth Lab 2023; Observatory of Economic Complexity 2023). The research outline focuses on three lines and thus employs three research methods.

Table 1. Variables (source: own processing).

Variable	Characteristics	Source
Dependent variables—Economic complexity indicators		
ECI	A country's rank—refers to the diversity and complexity of its export basket.	Harvard's Growth Lab (2023)
ECI research	Country's scientific output—scientific publications by field of research.	Observatory of Economic Complexity (2023)
ECI trade	Geography of trade—the sophistication of a country's exports.	Observatory of Economic Complexity (2023)
ECI technology	Patent applications by technology—geography of patent applications	Observatory of Economic Complexity (2023)
Control variables		
lnGDPpc	Natural logarithm of GDP per capita, GDP per capita is calculated from nominal GDP in EUR in market prices and countries' population.	Eurostat (2023)
Urbanization	Distribution of population by degree of urbanization, referring to cities + towns and suburbs as % of total population.	Eurostat (2023)
Tertiary education	Tertiary school enrollment, as % of all eligible children.	UNESCO (2023)
FDI	Foreign Direct Investments as% of GDP.	The World Bank (2023)
Economic recovery	Time dummy refers to 2013.	Own

First, we focus on absolute beta convergence. The absolute beta convergence is calculated when no other variables are involved in the estimation. To conclude for beta convergence, we assume $\beta < 0$. Absolute beta convergence states that countries converge to a common steady state (Allington and McCombie, 2007). When there is absolute beta convergence, computed λ (lambda) expresses the speed of convergence, and half-life presents the time taken to reduce the disparities by one-half (Allington and McCombie, 2007; Mendez, 2020). The OLS technique is used to calculate the absolute beta convergence running the linearized OLS regression.

Second, we focus on conditional beta convergence. The conditional beta convergence is calculated when a region-related variable (condition) is involved in the estimation. To conclude for beta convergence, we assume $\beta < 0$. Conditional beta convergence states that countries converge to their own steady state (Allington and McCombie, 2007). The condition refers to a different starting point of the country in the sample (Allington and McCombie, 2007; Chapsa et al., 2015; Goecke and Huether, 2016; etc.) and it is defined as a dummy variable considering 1 if the country is from the Western part of the EU and 0 otherwise. The construction of the condition mirrors the suppositions, that Eastern EU members are poorer compared to Western (Strielkowski and Höschle, 2016; Monfort et al., 2013; Beyaert and García-Solanes, 2014; etc.). Again, when $\beta < 0$, λ and half-life are calculated. Again, the OLS technique is used to calculate the conditional beta convergence running the linearized OLS regression.

Third, we calculate the conditional beta convergence by involving other control variables in estimation (see **Table 1**). The Barro-type regression is employed, too, when controlling for other factors that could influence the convergence process (Barro and Sala-i-Martin, 1992). In this case, we use a panel data approach and we estimate fixed-effect/random effect models, and dynamic panel data models based on the system GMM estimator (Blundell and Bond, 1998) to check for the endogeneity, while research provides estimations on the relationship between ECI and e.g., GDP per capita, human development or FDI (e.g., Mao and An, 2021; Khan et al., 2020; Zhu and Li, 2016) and vice versa (Soyyiğit and Michalski, 2022; Yalta and Yalta, 2021).

The choice of control variables is inspired by related research (Avom and Ndoya 2022; Pinheiro et al., 2022; Soyyiğit and Michalski, 2022; etc.). We refer to countries' wealth (using GDP per capita, similar to Pinheiro et al., 2022; Soyyiğit and Michalski, 2022; Mao and An, 2021; Yalta and Yalta, 2021) and size (measured by countries' population, enters the GDP per capita variable, and urbanization, that mirrors the distribution of the population into urban areas where the dominant part of the GDP is generated, mentioned e.g., in Moonen, Clark and Nunley (2019), foreign direct investments (FDI) (e.g., Soyyiğit and Michalski, 2022; Mao and An, 2021; Yalta and Yalta, 2021). human development (considering tertiary school enrollment, e.g., Yalta and Yalta (2021), while Soyyiğit and Michalski (2022) and Mao and An (2021) use expenditure on R&D or a number of researches as proxies to human capital), business cycle (related to GFC, e.g., Nagy and Šiljak, 2022; Pina and Sicari, 2021; Beyaert and García-Solanes, 2014) using a dummy for economic recovery in 2013 after the global financial crisis. The literature on economic recovery points to the year 2012 when countries started to implement policies concentrating on enhancing economic recovery (Makrevska Disoska et al., 2020; Paulus et al., 2017; FitzGerald, 2013). That is why we set a dummy variable for 2013. Besides, e.g., Avom and Ndoya (2022) consider the variable of economic stability.

To calculate the beta convergence in the case of economic complexity, we use the Barro and Sala-i-Martin (1992) model of economic convergence using the following equation:

$$\ln(y_{it}/y_{it-1}) = \beta_0 + \beta_1 \ln(y_{it-1}) + \varepsilon_{it} \tag{1}$$

where: $\ln(y_{it}/y_{it-1})$ is an annual GDPpc growth rate; $\ln(y_{it-1})$ is logarithm of GDPpc in previous period (t − 1). If $\ln(y_{it}/y_{it-1})$ is negatively correlated with $\ln(y_{it-1})$, i.e., if the coefficient $\beta_1 < 0$, we conclude for β-convergence.

The model of the beta convergence of economic complexity of 27 EU members in the period 1999–2021 developed from the model of economic convergence (Equation (1)), where GDP pc is replaced by the indicators of economic complexity could be rewritten to calculate the absolute beta convergence as:

$$\ln(ECI_{it}/ECI_{it-1}) = \beta_0 + \beta_1 \ln(ECI_{it-1}) + \varepsilon_{it} \quad (2)$$

where: $\ln(ECI_{it}/ECI_{it-1})$ is an annual growth rate of ECI; $\ln(ECI_{it-1})$ is logarithm of ECI in previous period (t−1). if $\beta_1 < 0$, we can conclude for beta convergence of economic complexity.

To compute the conditional beta convergence of the panel data model of beta convergence (Equation (3)), we add control variables to Equation (2)

$$\ln(ECI_{it}/ECI_{it-1}) = \beta_0 + \beta_1 \ln(ECI_{it-1}) + \gamma x_{it} + \varepsilon_{it} \quad (3)$$

where: $\ln(ECI_{it}/ECI_{it-1})$ is the annual growth rate of ECI; $\ln(ECI_{it-1})$ is the logarithm of ECI in the previous period (t−1) and x_{it} are control variables affecting ECI annual growth rate. Analogically, if $\beta_1 < 0$, we can conclude that beta convergence of economic complexity. In a dynamic panel data model, a lagged dependent variable enters the right side of the equation as a regressor, too. As mentioned hereinbefore, to measure economic complexity, four available indices of economic complexity are employed in the investigation: ECI, CI research, ECI trade, and ECI technology.

4. Results and discussion

When considering the absolute and conditional beta convergence in terms of economic complexity, the preliminary investigation (see **Figure 1**) provides us with some clarifying insights. The least-square fit projects in the case of ECI, ECI research, and ECI technology the negative relationship between initial values of logarithm ECI indices and their growth. Thus, we might expect the presence of beta convergence in the sample of 27 EU countries. At the base of **Figure 1**, too, we can consider conditional beta convergence, when projecting the values in the question factorized by the dummy variable for western and eastern EU members.

Conducting the first and second lines of the research, **Table 2** shows the results of absolute and conditional beta convergence, while λ and half-life are calculated, too. We can conclude for beta convergence when $\beta < 0$. In the case of absolute beta convergence, statistically significant $\beta < 0$ is observed in the case of ECI, ECI research, and ECI technology. In the case of ECI trade, there is no absolute beta convergence evidenced. The lowest value for the half-life is observed in the case of ECI, with the highest speed of convergence. The results of conditional beta convergence emulate the results of absolute beta convergence when beta convergence is not observed in the sole case of ECI trade. The lowest half-life and the highest speed of convergence are observed again in the case of ECI. When considering the condition which is set as a dummy variable referring 1 to western EU countries (old EU member states), the condition is statistically significant with a positive sign in the case of ECI research and ECI technology. It means that in Western countries the values of the growth of economic complexity are higher. It is in line with the findings of Hidalgo and

Hausmann (2009) and Özgüzer and Oğuş-Binatlı (2016), that countries with higher initial levels of economic complexity grow faster.

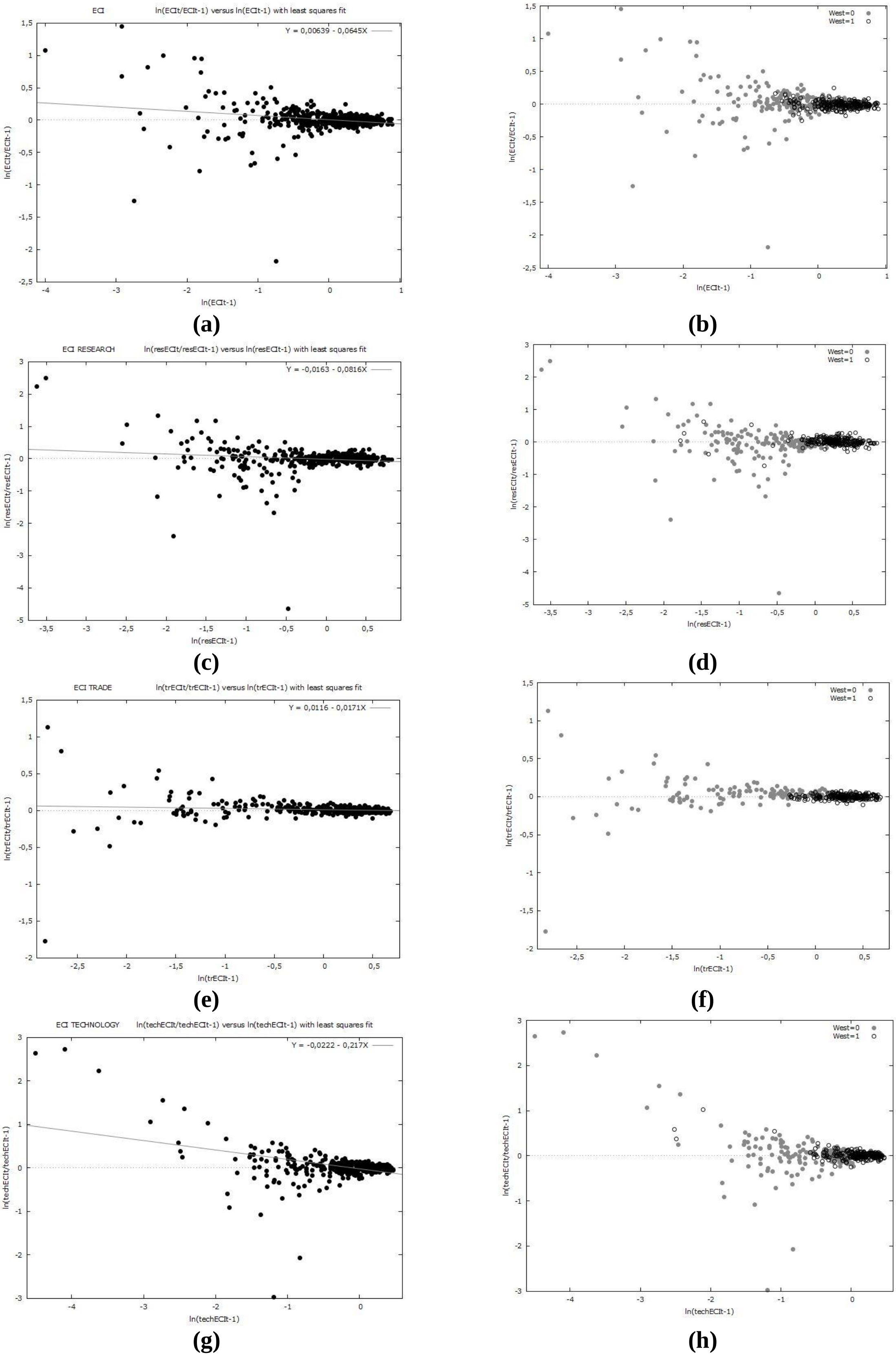

Figure 1. Scatterplots and factorized scatterplots (dummy for western EU countries) initial and growth values of ECI (Source: Own processing).

Table 2. Absolute and conditional beta convergence of 27 EU countries in 1999–2021.

	Absolute beta convergence				**Conditional beta convergence**			
	ECI	**ECI research**	**ECI trade**	**ECI technology**	**ECI**	**ECI research**	**ECI trade**	**ECI technology**
	Coeff./Signif.	**Coeff./Signif.**	**Coeff./Signif.**	**Coeff./Signif.**	**Coeff./Signif.**	**Coeff./Signif.**	**Coeff./Signif.**	**Coeff./Signif.**
Constant	−0.0652 (0.0552)**	−0.0151 (0.6190)	−0.0708 (0.2327)	−0.0311 (0.2666)	−0.0833 (0.1243)	−0.1790 (0.0052)***	−0.0527 (0.3655)	−0.0241 (0.0590)*
ln(ECIt−1)	−0.0849 (0.0115)***	−0.0402 (0.0402)**	0.0039 (0.9263)	−0.0367 (0.0145)***	−0.0878 (0.0141)***	−0.0716 (0.0074)***	−0.0748 (0.3686)	−0.0607 (0.0001)***
West (condition)	-	-	-	-	−0.0196 (0.6491)	0.1258 (0.0054)***	−0.3282 (0.2820)	0.0311 (0.0280)**
λ	0.0040	0.0019	NA	0.0017	0.0042	0.0034	0.0035	0.0028
Halflife	171.91	371.81	NA	408.11	165.92	205.16	196.13	243.47
R2	0.4253	0.4279	0.0019	0.7290	0.4365	0.8236	0.2798	0.8662

Note: *denotes significance level 0.1, ** 0.05, ***0.01. *P*-values in parentheses. Source: own processing.

In the third line of the research, we focus on adding other control variables to the estimations. The dummy referring to Western EU members is omitted from the estimations due to collinearity in the fixed effects and random effects models. However, the set of other control variables let us investigate conditional beta convergence in the sample of 27 EU countries.

The results of the estimations are displayed in **Table 3**. When deciding between fixed effects and random effect models we regard the Hausman test with a null hypothesis in favor of the random effects model. The p-values lower than 0.05 refer to the use of a fixed effects model. When evaluating the misspecification of the dynamic panel data model based on a two-step GMM system estimator, the Arellano-Bond first-order and second-order autocorrelation is considered. When evaluating the validity of instruments, the Hansen test is regarded with the null hypothesis is that instruments as a group are valid. The absence of second-order autocorrelation is not rejected and the Hansen test does not reject the validity of instruments.

In the case of the economic complexity measured as ECI, we estimated the fixed effects model, and then, to check the robustness of obtained results we estimated the system GMM model. Results show a statistically significant negative relationship between initial lnECI and ECI growth signaling the conditional beta convergence of 27 EU countries in the period 1999–2021. We proceeded in the same manner in the case of other ECI measures, too. All estimations evidence a presence of conditional beta convergence within the sample.

We controlled the beta convergence of economic complexity using the variables lnGDPpc, urbanization, tertiary education, foreign direct investments, and economic recovery when considering the business cycle. We can observe a stable statistically significant positive impact of lnGDPpc on the economic complexity growth observed in many studies, e.g., Pinheiro et al. (2022), Le et al. (2022), Mao and An (2021), Khan et al. (2020), Zhu and Li (2019). We confirm the previous assumptions about the starting point of wealthier and economically more complex economies and its impact on growth (discussed by Hidalgo and Hausmann 2009; Özgüzer and Oğuş-Binatlı 2016). Considering the effects of control variables, we have to raise the notice, that previous research usually does not rely on various ECI indicators (distinguishing among ECI, ECI research, ECI trade and ECI technology).

Table 3. Beta convergence and determinants of ECI growth of EU countries in 1999–2021.

	FEM				**System GMM**			
Dependent variable ln(ECIt/ECIt−1)	**ECI**	**ECI research**	**ECI trade**	**ECI technology**	**ECI**	**ECI research**	**ECI trade**	**ECI technology**
	Coeff./Signif.	**Coeff./Signif.**	**Coeff./Signif.**	**Coeff./Signif.**	**Coeff./Signif.**	**Coeff./Signif.**	**Coeff./Signif.**	**Coeff./Signif.**
Dependent (t−1)	-	-	-	-	−0.1956 (0.0048)***	0.1239 (0.1100)	0.2262 (0.0803)*	0.2595 (0.2911)
Constant	−1.0624 (0.0502)*	−1.9853 (0.001)***	−0.6284 (0.0069)***	−4.5255 (0.0332)**	−0.4235 (0.1240)	−2.6339 (0.0001) ***	0.0080 (0.9158)	−2.0518 (0.1742)
ln(ECIt−1)	−0.5838 (<0.0001)***	−0.3164 (<0.0001)***	−0.3731 (<0.0001) ***	−0.7575 (0.0013)***	−0.1865 (<0.0001)***	−0.3102 (<0.0001)***	−0.0464 (<0.0001)***	−0.3639 (0.0110)***
lnGDPpc	0.1714 (0.0193)**	0.1795 (0.0001)***	0.0630 (0.0139)**	0.4357 (0.0327)**	0.0798 (0.0252)**	0.2307 (0.0004) ***	0.0065(0.4247)	0.1695 (0.0763)*
Urbanization	−0.0027 (0.0033)***	0.0020 (0.0738)*	0.0001 (0.9776)	−0.0006 (0.7406)	−0.0013 (0.0691)*	0.0034 (0.0091) ***	−0.0004 (0.0132)**	0.0027 (0.2551)
Tertiary education	−0.0062 (0.0069)***	0.0007 (0.4895)	0.0003 (0.6442)	0.0015 (0.4969)	−0.0036 (0.0112)**	0.0012 (0.1953)	−0.0005 (0.0351)**	0.0021 (0.2597)
FDI	−0.0011 (<0.0001)***	0.0001 (0.9445)	0.0005 (0.0654)*	−0.0001 (0.7914)	−0.0018 (<0.0001)***	−0.0010 (0.2485)	0.0004 (0.0049)***	0.0003 (0.6637)
Economic recovery	0.0512 (0.0564)*	−0.0481 (0.3708)*	0.0065 (0.6828)	−0.0516 (0.0931)*	0.0364 (0.0647)*	0.0445 (0.4747)	0.0306 (0.0011)***	−0.1193 (0.0001)***
R2	0.3640	0.3063	0.6026	0.4526	-	-	-	-
Hausman test	(0.0000)	(<0.0001)	(<0.0001)	(<0.0001)	-	-	-	-
AR1	-	-	-	-	0.2442	0.1199	0.1225	0.2211
AR2	-	-	-	-	0.2822	0.1353	0.7374	0.6937
Hansen test	-	-	-	-	(0.4556)	(0.5247)	(0.9721)	(0.8423)

Note: *denotes significance level 0.1, ** 0.05, ***0.01. *P*-values in parentheses. Source: own processing.

Besides, almost half of our sample consist of post-communistic countries overcoming the economic transition in the monitored period. That might influence the final results, too. However, it would be beneficial to take it into account when comparing them to the results of earlier research in the field of economic complexity. The literature on ECI determinants suggests a positive relationship between the FDI and ECI. A positive relationship is observed e.g., by Khan et al. (2020) and Avom and Ndoya (2022), while Mao and An (2021) find a both positive and negative relationship between investment and ECI. Yalta and Yalta (2021) observe a negative but statistically not significant effect. Our results evidence both positive (ECI trade) and negative (ECI) relationship between the FDI and ECI. The negative sign in the case of ECI is the opposite of the expectations. In our sample, higher FDI was tied to less developed EU countries in transition usually located in the Central and Eastern parts of the EU (Kalotay, 2017). The decrease in FDI in the mentioned countries was observed in the period after the global financial crisis, while Kalotay (2017) mentions that actually, countries in question face problems with a low-skilled labor force when aiming to attract FDI. The labor quality, human development, or human capital is usually measured by the number of schooling years and school enrollment, the most frequently the secondary school enrolment (Khan et al., 2020; Yalta and Yalta 2021). Mao and An (2021) found a positive relationship between human capital and ECI. Zhu and Li (2019) and Khan et al. (2020) find a positive relationship between secondary school enrollment and ECI. Yalta and Yalta (2021) mention that primary and secondary education are the core stones of economic development in developing countries, while Mao and An (2021) discuss human capital as an important factor influencing labor quality. Our sample consists of developed countries, and for this reason, we focus on tertiary school enrollment as a proxy for human capital, similar to Yalta and Yalta (2021). Our results show a negative relationship between tertiary school enrolment and ECI growth, oppositely to the expectation. In a very similar line, Yalta and Yalta (2021) consider surprising their findings about the not statistically significant relationship between tertiary school enrolment and ECI while expecting its undoubted positive impact on ECI. According to Nadoveza Jelić and Gardijan Kedžo (2018), central and eastern EU countries suffer from lower levels of quality inputs to tertiary education compared to Western EU members. Besides, higher values of tertiary school enrolment are observed in the case of central and eastern countries (UNESCO, 2023). Thus, the gain from the tertiary educated population is not achieved in those countries. When controlling for the effects of the population on ECI, we use a variable referring to urbanization when witnessing the increase of urban population in the EU countries mentioned e.g., by Moonen, Clark and Nunley (2019). We find both positive and negative effects on different ECI variables, while the previous research provides us with similar ambiguous findings, e.g., Avom and Ndoya (2022) observe a positive relationship between population and ECI, while Mao and An (2021) find a negative relationship between population and ECI. The effect of the global financial crisis was considered when examining the economic convergence e.g., Cabral and Castellanos-Sosa (2019) and Borsi and Metiu (2015). Cabral and Castellanos-Sosa (2019) observe the decrease in the rate of convergence, Borsi and Metiu (2015) discuss that the global financial crisis revealed the EU countries' different fundaments when considering the real convergence. Monfort et al. (2018) observed higher inequalities between EU countries in terms of income since the financial crisis in 2007. In the case of economic complexity, Avom and Ndoya (2022) investigate the impact of the economic stability of the country on economic complexity finding that economic stability enhances the economic complexity. In our research, we consider the effect of the global financial crisis in terms of economic recovery tied to the year after 2012, (see Makrevska Disoska et al., 2020; Paulus et al., 2017; FitzGerald, 2013). Having in mind, that times of economic recovery are tied to economic expansion that leads to higher economic stability, we expect its positive impact on ECI growth (in line with Avom and Ndoya, 2022). However, observed results cannot provide us with a clear insight, when in the case of ECI technology, the relationship is negative. It might turn us to Borsi and Metiu (2015) about different initial fundaments that cause obvious inequalities in the convergence in the period of crisis.

5. Conclusion

The economic complexity of the country refers to the knowledge of society (Balland and Rigby, 2017) when concentrating on the aspect, of how countries perform their economic activities (Pugliese and Tacchell, 2021). The literature on economic complexity admits, that the economic complexity mirrors the countries' economic strength and future growth prospects (Özgüzer and Oğuş-Binatlı, 2016; Schetter, 2021). Besides, the literature review on the statistical inference between the economic strength of countries and economic complexity confirms a positive relationship (Avom and Ndoya, 2022; Pinheiro et al., 2022.; Le et al., 2022; etc.).

In this research we focus on the beta convergence of 27 EU countries in the period 1999–2021 according to their economic complexity, considering the economic complexity as a proxy for the economic strength of the country (Schetter, 2021). Based on the assumption, that the EU countries converge economically, we assume, that they converge in terms of economic complexity, too. We use the economic complexity indicators drawn from Harvard's Growth Lab (2023) and MIT's Observatory of Economic Complexity (2023). We run the Barro and Sala-i-Martin (1992) type of econometric regressions to examine the absolute and conditional beta convergence. Our results show, that EU countries converge when considering the beta convergence of economic complexity.

However, the research on economic complexity has enjoyed scientific attention in the last decades. Further research might focus on the potential of increasing the economic complexity and its constraints considering countries with specific limitations in the context of various expressions of economic complexity, meaning various types of ECI indicators.

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