

Analysis of Economic Convergence in the European Union

Adrian LUNGU

Bucharest University of Economic Studies, Bucharest, Romania

lungugeorge19@stud.ase.ro

Abstract. *The article analysis the economic convergence of member states of the European Union through ten main macroeconomic indicators. Employing a combination of statistical methodologies encompassing, such as descriptive statistics, multiple regression and ANOVA analysis, the research intends to reveal an updated outlook and also the big picture of economic convergence process within the European Union. Its results, analysing economic indicators, show the serious convergence trends between economies of EU-27 member states in general, but particularising, we can observe variations of the progress for each member state. Also, has been remarked that when the GDP per capita has increased in most of the member states, the differences have significantly decreased, these still exist. Moreover, convergence is discernible in inflation rates, unemployment rates, and trade balances. In the same way, the analysis pointed out also the differences that exist between member states, which have to be treated and separated, but together through inclusion policies, social and economic, to have as a final goal, the absolute convergence to be realised through shorter period of time than the actual trend. Premises, likewise, the realities that exist in the present can lead to a deeper and feasible convergence, even if it can offer the growing rhyme in comparing some states with others. In conclusion, the article highlights the fact that is much more than necessary that political strategies of member states individually, and also member states of the European Union to get together regarding aligning to the best economic and social level.*

Keywords: Convergence, EU-27, GDP per capita, ANOVA, Cohesion policies.

Introduction

Regarding european integration, the economic convergence between member states represents an essential aim for european integration and cohesion, having as main purpose harmonising living standards between member states and consolidating economic and social solidarity. In what concern the context of successive extensions and global challenges in the last two decades, including the financial crisis 2008-2010 and the COVID-19 pandemic, the economic convergence analysis becomes essential for understanding the european economic dynamic and for its resilience.

The purpose of this study is to investigate the economic convergence within UE-27 states from 2000 year to 2021 year. In order to achieve this goal, we realised a detailed analysis of the evolution of ten macroeconomic indicators that are relevant in this period of time. The justification of choosing these indicators was their ability to capture the economic performance and the regional disparities between the member states. The differences identified between regions maybe addressed through targeted regional or national policies.

The importance of this study stays in its capacity to provide significant information about the degree of economic convergence between member states of the European Union. This thing may have important implications for economic and regional policy of EU, and also for policy formulation decisions on an european institutions level. Knowing economic disparities between regions can facilitate the balanced regional development and can contribute to reducing economic gaps between different parts of the EU. This thing may have a positive impact for the citizens living standards and can also contribute to social cohesion. Moving forward, this article will explore the analysis's methodology, the research hypothesis and the obtain results, to offer a better

understanding of how the economies of the 27 state members of the EU had developed in the last two decades and if there were tendencies of convergence or divergence.

This research has the potential to contribute to a more profound understanding of the factors that influence economic convergence and to development of efficient strategies of public politics for promoting economic cohesion in the EU.

The speciality literature analysis regarding economic convergence in the EU is reveals a constant preoccupation for the dynamic and factors that influence this complex process. The academic and non-academic debates had concerned on the rhythm evaluation and the convergence's profoundness between member states, with a special interest for the way that different policies and different economic contexts contribute to this process. Even though the existing literature is vast, having empirical analysis, and theoretical analysis, are observed a variety of approaches and conclusions, highlighting the complexity and diversity of this research field, as the associated challenges. In this study, we approach the economic convergence analysis in the EU-27 through a properly methodology, that implicates utilising comprehensive sets of dates and application of advanced statistical methods.

This section details the key-components of our methodology, offering transparency and facilitating the study reapplication. The data's sources for this study include known internationally bases of data, such as Eurostat and World Bank. Those data are selected to assure their relevance in the context of economic convergence and are verified for coherence and reliability. To analyse the data, it's used descriptive analysis to offer an overview image of the data's sets, including central tendencies, the ANOVA variable analysis which allows evaluation of significative variations in economic performance that may influence the convergence between member states, such as multiple regression that plays an important role in macroeconomic indicators analysis through simultaneous evaluation of the impact of much more independent factors to a dependent macroeconomic variable, offering a large understanding of the forces that shape the economy.

By combining statistical and econometric methods, the study shows a comprehensive and approach capable of capturing the complexity of economic convergence in the EU-27. This methodology assures relevance of the analysis by giving a better understanding of economic processes which are the basis the convergence between EU member states. The analysis shows mixed tends of the economic convergence between EU-27 member states in 2000-2021.

Literature review

This chapter handle from the beginning the relevance and importance of statistical and econometrical methods, such as: descriptive statistics, multiple regression analysis and ANOVA analysis, as well their importance in the research actual context.

These methods are very important form analyses and interpretation of data set. As well, these allows hypothesis testing, recognized the relations between dependent variables and predictors (independent variables), after to conclude accurate based on data set analyses.

Radonov et al. (2023) investigate the relation between the macroeconomics determinates and the bank's performance using multiple regression analysis. This method allows to identify the quantify the relation between dependent variable and independent variables. They used regression analysis on panel data, applying fixed effects and also random effects, as it is indicated by Hausman test.

According to the analysis made by Bucur and Stangaciu (2015), on the economic and social convergence in EU member states between 1995 and 2012, using regression for testing convergence β for GDP per capita and the Human Development Index a distinct convergence was observed in these fields, at different rates. The study highlights a significative convergence,

supported by negative beta coefficients and F significative values in ANOVA analysis, what is demonstrating that countries with lower development initial levels tend to grow faster, thus reducing disparities reporting with developed countries. These underline the necessity of a diversified approach and EU politics coordination to promote not only the economic increase, but social progress, thus contributing at harmonies developing and included in the Union.

Bucur's (2012) study addresses the process of real convergence in the economies of the European Union, applying a regression model to examine β convergence at the national level for the EU-27, EU-15 and EU-10+2 groups, as well as for regional level for the 271 NUTS 2 regions, using the GDP per capita adjusted to purchasing power parity as the key indicator. The integrated methodological approach, which includes both regression tests and ANOVA, allowed the quantification of the marginal effect of GDP per capita growth caused by changes in initial economic and social conditions.

Statistical signification's confirmation following ANOVA analysis, rejected the null hypothesis of lack of convergence in all analysed situations. F test value shows that significative differences between groups and regions analysed. The conclusion highlights that, even though the convergence process is in progress and strengthen, this shows significative differences between regions and countries groups. In the same idea the remarkable fact is the the dynamic is slow at the level of regions. Hayes and Hayes (2016) study treat the real convergence process within euro countries analysing many macroeconomic indicators, in period form 2002 year to 2013 year.

Their study research, using cluster analysis, is how to form even how evaluating these clusters. After utilizing the cluster analysis, the authors use ANOVA analysis in order to confirm significative differences between clusters, shows that the way which different economic, political and social conditions influence the pace or intensity ate alignment of the states.

In their paper, Haller et al. (2021) investigate the dynamics of tourism growth in the 28 member states of the European Union between 2012 and 2018, with a particular focus on the analysis of economic convergence in the tourism sector. Their study shows a detailed perspective, at the same time checking the measure in which that the income generated by these services contribute to the economic growth and if there is a convergence tend between the EU countries in this economic sector. Applying the ANOVA analysis, joined by Durbin-Watson test, in ort to catch the autocorrelation, offer a detailed image on the convergence process in tourism field. The result shows a intension low and slow convergence, showing the fact the specific elements of travel did not have a significative impact to rush the convergence process in UE. They emphasise that, despite the increase in income from accommodation observed in most member states, European convergence remains a slow process, influenced by factors other than those directly related to tourism.

In their research, Mrkvička et al. (2020) address the phenomenon of tax decentralization in european countries by analysing data regarding governmental expenses of 29 member states of the European Union and EFTA member states between 1995 and 2016.

The data has been dividing in three distinct categories, each one reflecting the level of political and economic integration. The study uses ANOVA analysis, more, offer the different graphic interpretation, that allow comparison between groups and are able to identify specific difference between them. The main conclusions of the study underline a possible modification of results in case of comparing a big number of groups, a problem that can be fixed by increasing permutation number.

This methodological approach offers valuable information for Adu et al. study (2023), which explores Google Trends data potential in provision of unemployment rates. The studies presented above, confirm and underscore the way which the methodological research can inspire

and up to date the research in different fields. These analysis and prediction technics can be used in different domains to find the best solutions.

The technologic progress and accumulation of data at large scale needs continuing development in statistic methods. Passing from a traditional technique such as linear regression and ANOVA to more complex such as LSTM neural networks and combined ARIMA-ANOVA marks a significative step toward in analysis and prediction capability. This suite of econometric and statistical analyses provides beside a better and more accurate analysis in the present study, new points of view, which highlights their role in research. Going deeper using statistical and econometric analysis in other fields, not only in the economic field, shows their versatility.

Methodology

In order to investigate the economic convergence degree within European Union member states throughout the period 2000-2021, we decided to analyse the economic convergence in this context, by using set of statistical and econometric methods to obtain an understanding of the economic relationships between analysed countries.

The first step into analysing, it was descriptive statistics, that represents a very important step in understanding the data set. This analysis has allowed identifying a general and comprehensive perspective of the selected macroeconomic indicators. Through this method we managed to determine the data set characteristics for a better understanding of it. The median, on the other hand, provided us with a view of the middle values of the data set, providing a perspective resistant to outliers or anomalies. This proves important in economic data because a single anomaly could lead to an entirely wrong assumption regarding an entire model. By calculating standard deviation and interquartile interval we analysed the data dispersion. These approaches assist in evaluating deviation variation and data spread around mean and offer consistent economic indicators variation display.

A lower standard deviation indicates a tighter distribution of mean data, while a bigger value shows a bigger dispersion, which can indicate a significative economic diversity between member states of European Union. By exploring quartiles, we understood the data distribution, the first and the third quartile, offering a clearer perspective of the way this data are distributed in the range from lower to highest values. This fact allowed us to identify the distribution, and also to disclose outliers' values through observing the values that significantly differ from the most data.

This stage of descriptive statistics provided an understanding of the current state of economic indicators as well as a solid foundation for more in-depth investigations for further approaches such as multiple regression and ANOVA. In order to obtain a real and comprehensive picture of economic processes, we have selected a set of specific macroeconomic indicators: exports, imports, foreign direct investment inflow (FDII), foreign direct investment outflow (FDIO), gross domestic product growth, inflation rate, unemployment rate, public debt and budget deficit. These indicators were chosen for their performance in assessing economic aspects and integration within the European bloc. In this framework, GDP per capita was set as the main dependent variable for our multiple regression model, given the objective of an analysis of living standards and economic convergence between member countries.

Regarding collecting, and then the data analysis, we searched for official sources and trustworthy such as Eurostat and World Bank, which represent the main sources for the analysed data set. These sources offer access to updated and uniform data, which allows a correct analysis regarding computation of the economic performances in the EU-27. Using these sources was fundamental for a better understanding of the problems and/or economic convergence processes in

the European Union. This approach had proposed to offer a clear image based on real data regarding trend and dynamic between member states. The last step of the analysis was applying ANOVA analysis to examine, and eventual, observe if there is differences between countries groups. Groups of states were formed by a previous analysis of cluster analysis. We used cluster K-mean analysis, with four cluster that segmented states in four distinct groups. This methodological approach took part in connecting variations between formed groups, and also to test the hypothesis of the significative differences, regarding the convergence level evaluation. Before we start the statistical analysis and echometric, data have suffered a serious and strict cleaning process to be sure of the data set's integrity. This process took the data evaluation to discover and eventually correct any errors or missing values.

The examination of economic convergence within the EU-27 will involve utilizing a multiple regression model to assess how various independent factors influence GDP per capita, the selected dependent variable.

The multiple regression model was structured as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots \beta_n X_n + \varepsilon \quad (1)$$

where,

Y - dependent variable.

β_0 - is the intercept of the equation, representing the mean value of Y when all independent variables ($X_1, X_2 \dots X_n$) are equal to 0.

$\beta_1, \beta_2 \dots \beta_n$ - regression coefficients, each measuring the mean change in Y associated with a unit change in the corresponding independent variable, holding all other variables constant.

$X_1, X_2 \dots X_n$ - the independent variables or predictors of the model.

ε - the error term, which represents all other factors that influence Y but are not included in the model. It captures the variation in Y that cannot be explained by the independent variables.

In order to identify the best model have been explored two regression analysis method: fixed effect regression model and random effect regression model. These methods allow control over the unobserved variables, that can influence the dependent variable in time or between entities. The fixed-effects model captures country-specific variability by including a unique term for each entity, assuming that these differences do not change over time.

In contrast, the moving effects model allows the coefficients to vary both between entities and over time, providing a more flexible framework for analyzing how the relationships between the independent and dependent variables change in our dynamic context. The best model was chosen as a result of Hausman test.

$$H = (\hat{\beta}_{FE} - \hat{\beta}_{RE})' [Var(\hat{\beta}_{FE}) - Var(\hat{\beta}_{RE})]^{-1} (\hat{\beta}_{FE} - \hat{\beta}_{RE}) \quad (2)$$

H- statistical value of the Hausman test

$\hat{\beta}_{FE}$ - the vector of coefficient estimates obtained from the fixed effects model;

$\hat{\beta}_{RE}$ - the vector of coefficient estimates obtained from the random effects model;

$Var(\hat{\beta}_{FE})$ - variance-covariance matrix of coefficient estimates from the fixed-effects model;

$Var(\hat{\beta}_{RE})$ - the variance-covariance matrix of coefficient estimates from the random effects model.

$[Var(\hat{\beta}_{FE}) - Var(\hat{\beta}_{RE})]^{-1}$ - the inverse of the difference between the variance-covariance matrices

Following the previous criteria, the regression with fixed model offers an optimum balance between data and the model's complexity.

Further, we used ANOVA analysis in to order to evaluate the differences between four groups of countries, through cluster analysis previously made.

The ANOVA analyses allows identifying performance variation between country groups for every economic variable. It as well test, two main hypotheses: if there are differences between means within the four country groups and between those groups, or not. The one-way analysis of variance is structured as follows:

$$SS_{total} = SS_{between} + SS_{within} \quad (3)$$

SS_{total} - the total sum of squares, which measures the total variation in the data;

$SS_{between}$ - sum of squares between groups, which measures the variation between group means;

SS_{within} - sum of squares within groups, which measures the variation within each group.

$$SST = \sum_{i=1}^k \sum_{j=1}^{n_i} (Y_{ij} - \bar{Y}_{..})^2 \quad (4)$$

Y_{ij} - observation j from group i ;

$\bar{Y}_{..}$ - general average of all observations;

k - the number of groups;

n_i - number of observations in group i

Merging these research methods allowed to obtain a more profound understanding of the structure and evolution of the economic performance of the analysed countries.

Following the integration of the result, obtained after each methodological step, we are able to see a complete and complex big picture of the relevant indicators that influence the economies. As well, we had an image of the way in which these macroeconomic indicators are interacting. As well, we had an overview of the way in which they are interacting. In order to have a proper analysis is important to take into account the limitation of each used methods. Over all, the study shows the importance of economic convergence, as well as solutions to attain at the level of UE-27.

Case study

We started the analysis with research of descriptive statistics for each of the 10 selected economic indicators of the EU-27 countries. This section will allow us to identify general trends, variations and salient features of the data set, thus laying the groundwork for further and more detailed investigations.

For this objective, we shall initially present comparative analysis tables for the beginning (Table 1) and the end (Table 2) of the analysed period, 2000 and 2021.

Afterwards comparison between them, we will be able to identify a picture over the evolution, such as the major changes that took place the within the specific period of the European Union.

In addition, the analysis of annual variations and significant fluctuations will be supported by radar charts, which will underline the data distribution, medians and interquartile variation for each indicator. This will help us identify outliers and better understand the dispersion and concentration of values for each indicator.

Table 1. Descriptive statistical values for the year 2000(EU 27 countries)

Variable	Min	1st.Qu	Median	Mean	3rd.Qu	Max
Exports	21.6	29.7	43.3	51.29	63.8	147.6
Imports	24.8	34.2	42	51.7	62.2	128.4
FDII	0	3.71	6.63	8.56	9.56	37.57
FDIO	-0.03	0.16	1.31	5.63	8.28	36.56
GDP_growth	1.17	3.71	4	5.13	5.46	19.68
Inflation	1.1	2.6	3	5.89	5.1	45.7
Unemployment	2.35	5.22	7.92	9.3	13.58	19.06
Public_debt	5.1	30.65	52.2	49.44	59.1	109.6
Budget_deficit	-12.6	-3.6	-2.4	-1.73	0	6.9
GDP_per_capita	7.39	8.42	9.42	9.27	10.09	10.8

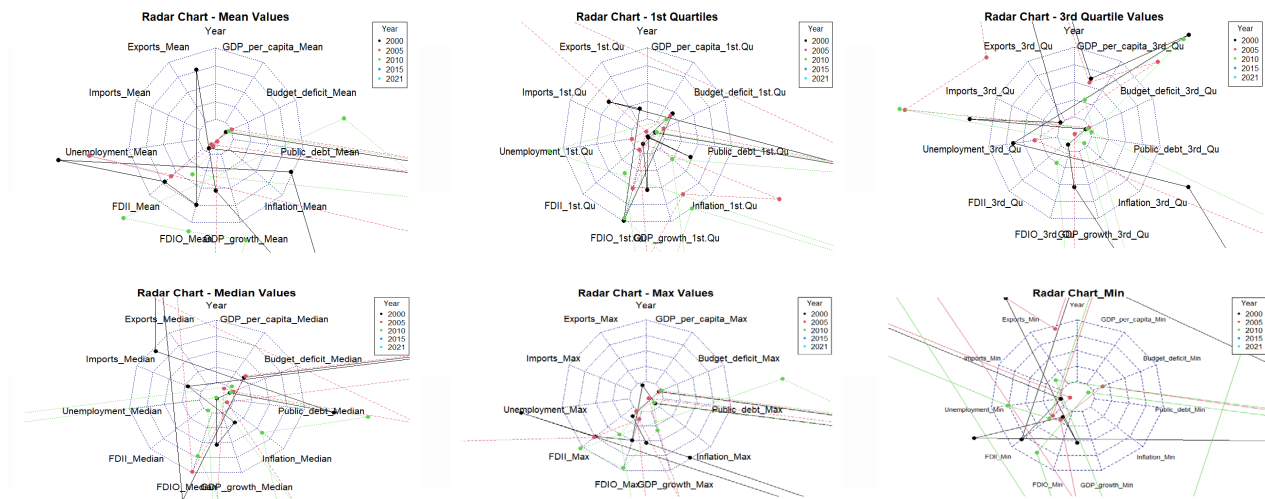
Source: Eurostat & World Bank. The data was processed by the author with statistical software R.

Table 2. Descriptive statistical values for the year 2021(EU 27 countries)

Variable	Min	1st.Qu	Median	Mean	3rd.Qu	Max
Exports	29.4	43.95	61.3	72.67	83.35	211.4
Imports	30.4	45.4	59.6	68.17	79.3	176.7
FDII	-10.65	0.8	2.53	2.6	3.2	24.46
FDIO	-12.38	0.19	1.54	4.49	3.96	44.26
GDP_growth	2.63	4.86	5.98	6.38	7.38	13.59
Inflation	0.6	2.1	2.8	2.87	3.35	5.1
Unemployment	2.81	4.9	6.19	6.61	7.56	14.78
Public_debt	17.8	43.7	61.1	72.16	90.9	195
Budget_deficit	-8.8	-6.6	-4	-3.94	-2.05	4.1
GDP_per_capita	9.42	9.97	10.33	10.43	10.87	11.81

Source: Eurostat & World Bank. The data was processed by the author with statistical software R.

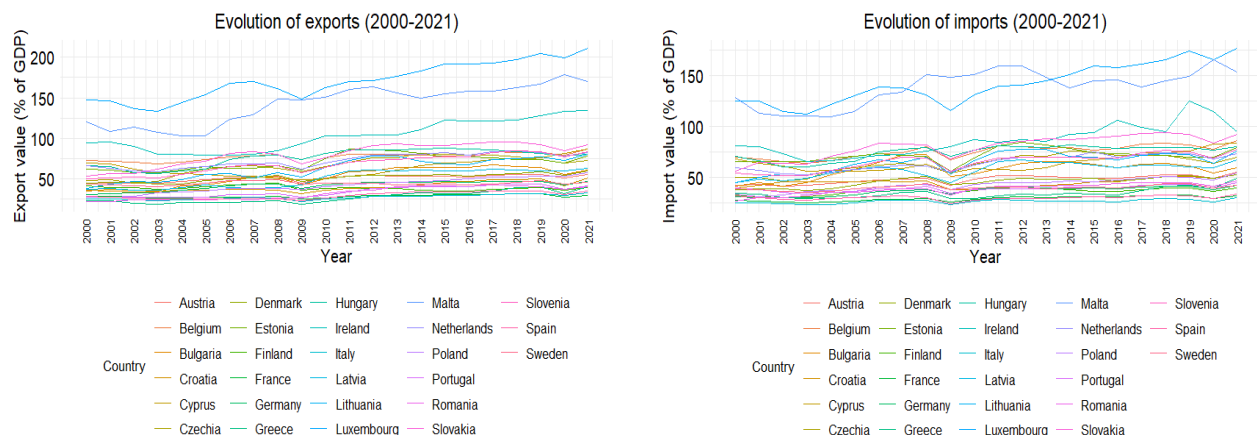
The tables above, which shows the descriptive statistics at the beginning and the end of the analysed period, present a general trend of economic convergence growth in the European Union. Although the differences between countries have decreased gradually economic disparities persist and are influenced by more factors, such as economic policy, natural resources and global economic evolution.



Graph 1. Radar charts for measuring dispersion and trends

Source: Eurostat & World Bank. The data was processed by the author with statistical software R.

Summarize, the radar charts show the positive evolution of trends and a strengthening of the most macroeconomic indicators for EU-27, fact that suggest a general improve of economic performance. Uninterrupted growth of GDP per capita, such the mean and maximum unemployment decrease suggest a possible reduction of disparities between member states and also economic performance of convergence. In order to offer an instant and clear visual understanding of the data they were included and descriptive graphics analyses for each analysed economic indicator. These facts illustrate evolution in the analysed period, underlining key moments of the economic growth, decrease or stability. Lines graphs show trends in time.

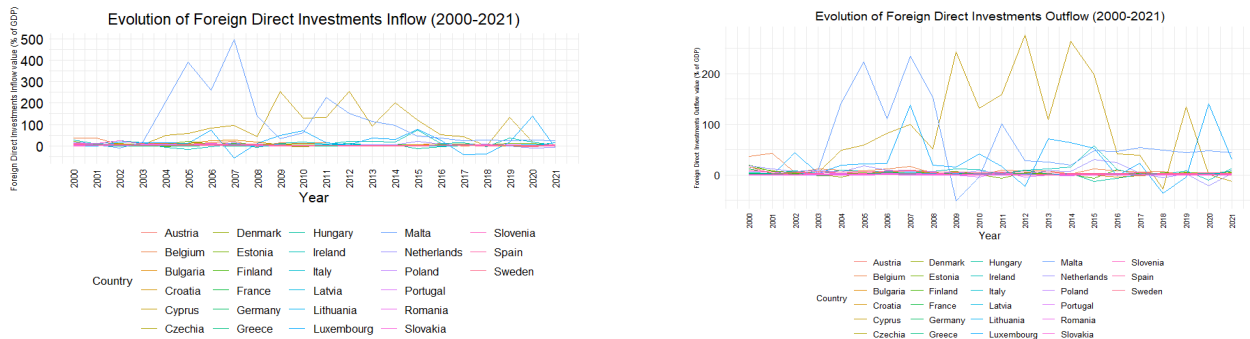


Graph 2. Evolution of export and import indicators (2000-2021)

Source: Eurostat & World Bank. The data was processed by the author with statistical software R.

After analysing the exports trends from 2000 to 2021(Graph 2) stand out an initial weighted growth period, but constant. This period is followed by the significant mess that showed up during the global financial crisis, the exception being the economies pointed towards financial and technological orientation.

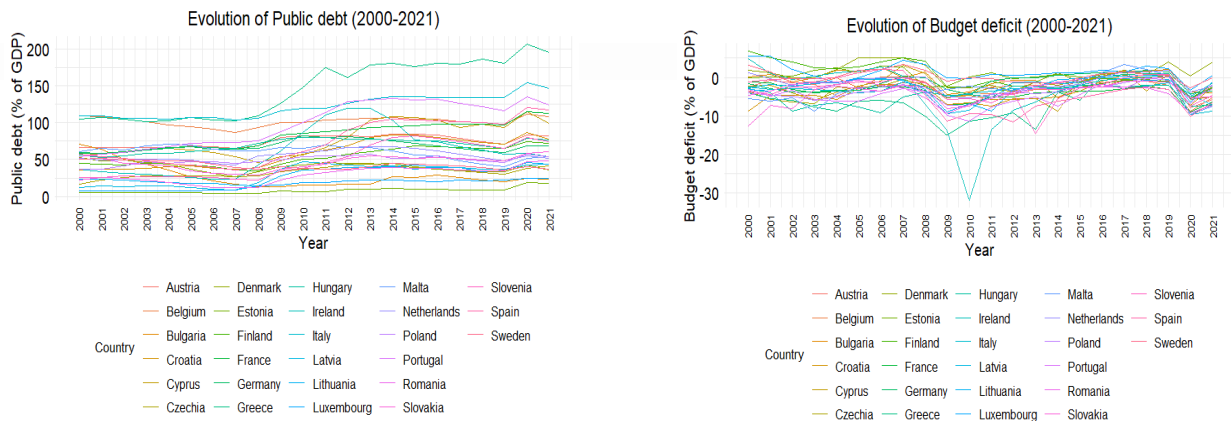
These economies pointing out resilience and versatility to extreme shock. On the other hand, the evolution of import (Graph 2) at the same time shows an almost identical image of the pre-crisis increase, which is followed by outstanding contraction as answer to the global financial crisis. The trend of these indicators illustrates the way in which the major economic events are able to influence, even reshape international commercial flows.



Graph 3. Evolution of FDI and FDI O indicators (2000-2021)

Source: Eurostat & World Bank. The data was processed by the author with statistical software R.

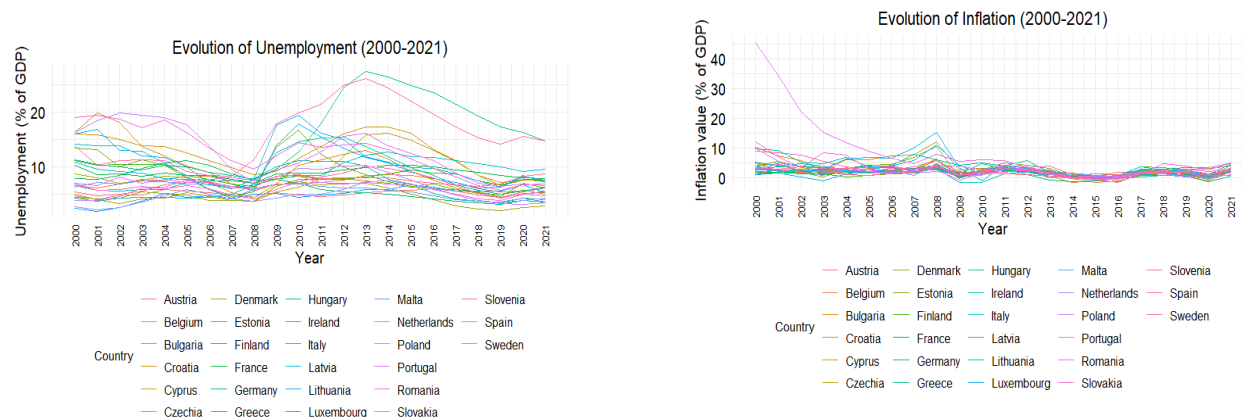
FDI's analysis (Graph 3) highlights pre-crisis growth and a post-2008 decline, with Cyprus highlighting large inflows, while FDI O volatility in Luxembourg and Malta reflects major transactions outpacing real economic activity. The data suggests a general trend of focus on attracting foreign investment to most European economies, with FDI O remaining modest relative to GDP, highlighting countries' differing international investment strategies.



Graph 4. Evolution of Public debt and Budget deficit (2000-2021)

Source: Eurostat & World Bank. The data was processed by the author with statistical software R.

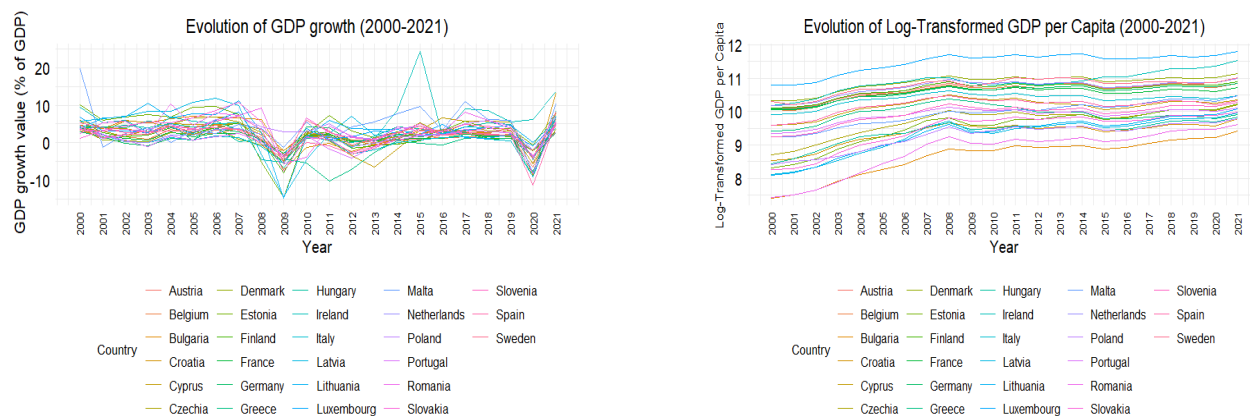
Variations in public debt levels (Graph 4) between countries highlight different approaches to fiscal policies and debt management capacity, with critical thresholds such as 100% of GDP, signalling challenges to fiscal sustainability. On the other hand, regarding the budget deficit (Graph 4) distinguished very clear a increase for budget deficit from 2008 to 2010, then the situation has been stabilized almost in normal interval, even bigger before the financial crisis. As well, we can remark that budget deficit has increased again during COVID-19 pandemic crisis.



Graph 5. Evolution of Unemployment and Inflation (2000-2021)

Source: Eurostat & World Bank. The data was processed by the author with statistical software R.

Changes of the unemployment rate (Graphic 5) reflect the influence of economic changes over labour market. The graphic represents an image in which unemployment peaks are associated with various recessions that took place over the analysed period and highlights a close connection between economic performance and unemployment. The same graphic (Graphic 5), presents a inflation rate stability that highlights the success of monetary policy of the analysed states in keep it in acceptable limits, such as controlling and managing it by the governments or central banks.



Graph 6. Evolution of GDP growth and GDP per capita (2000-2021)

Source: Eurostat & World Bank. The data was processed by the author with statistical software R.

The observed fluctuations in GDP growth (Graph 6) underline the sensitivity of national economies to global economic changes, with the 2008-2009 period marking a significant contraction associated with the impact of the global financial crisis on economic development. The general trend of GDP per capita growth (Graph 6) shows steady economic progress in most countries.

Following the above analyses, having a solid understanding of the behaviour of each economic indicator, the next step involves the application of multiple regression models.

This step is essential for evaluation the relationships and mutual impact between independent and dependent variables, allowing us to discover some of the determinants of economic convergence between EU-27 countries.

The first step is to apply regression to the panel dataset to assess the influence of specific indicators on the dependent variable. This approach allowed to obtain an overview of dynamics and relationships between variables.

The specific multiple regression formula with fixed effects is as follows:

$$GDP_per_capita_{it} = \alpha_i + 0.01457124 * Exports_{it} + 0.00543489 * Imports_{it} - 0.00038703 * FDII_{it} + 0.00203009 * FDIO_{it} - 0.01683274 * GDP_{growth}_{it} - 0.03027001 * Inflation_{it} - 0.04467767 * Unemployment_{it} + 0.00116384 * Public_debt_{it} - 0.01719357 * Budget_deficit_{it} + \varepsilon_{it} \quad (5)$$

where,

$GDP_per_capita_{it}$ - the value of GDP per capita for country i in year t . It is the dependent variable, the variable we are trying to explain or predict through the regression model.

α_i - country fixed effect i . This is a unique constant for each country that captures all unobserved time-varying characteristics for that country.

$Exports_{it}$, $Imports_{it}$, $FDII_{it}$, $FDIO_{it}$, GDP_growth_{it} , $Inflation_{it}$, $Unemployment_{it}$, $Public_debt_{it}$, $Budget_deficit_{it}$ - the values of the independent variables for country i in year t .

ε_{it} - the term error or disturbance for country i in year t . This term captures all influences on GDP per capita that are not explained by the variables in the model.

Following regression with fixed models, the output is as follows (Table 3):

Table 3. Summary of regression analysis for the dependent variable GDP per capita (fixed models)

Variable	Estimate	Std.Error	t.value	Pr
Exports	0.014571	0.002829	5.1508	3.60E-07
Imports	0.005435	0.00345	1.5756	0.115694
FDII	-0.00039	0.000553	-0.7	0.48421
FDIO	0.00203	0.000687	2.9555	0.003254
GDP_growth	-0.01683	0.0031	-5.4297	8.44E-08
Inflation	-0.03027	0.003709	-8.1618	2.21E-15
Unemployment	-0.04468	0.003753	-11.9059	<2.2e-16
Public_debt	0.001164	0.000777	1.4974	0.134857
Budget_deficit	-0.01719	0.00387	-4.4431	1.07E-05
Total Sum of Squares	80.856			
Residual Sum of Squares	31.86			
R-Squared	0.60596			
Adj. R-Squared	0.58125			
F-statistic	95.3457 on 9 and 558 DF			
p-value:	2.22E-16			

Source: Eurostat & World Bank. The calculus was performed by the author with statistical software R.

The specific multiple regression formula with random effects is as follows:

$$\begin{aligned} GDP_per_capita_{it} = & 9.58263219 + 0.01715008 * Exports_{it} - 0.00457519 * Imports_{it} - \\ & 0.00067974 * FDII_{it} + 0.00206281 * FDIO_{it} - \\ & 0.01608462 * GDP_{growth}_{it} - 0.03300691 * Inflation_{it} - \\ & 0.05207606 * Unemployment_{it} + 0.00336392 * Public_debt_{it} - \\ & 0.01375562 * Budget_deficit_{it} + u_i + \varepsilon_{it} \end{aligned} \quad (6)$$

where,

9.58263219 - the intercept or constant, and represents the average value of GDP per capita when all independent variables are zero.

GDP_per_capita_{it} - the value of GDP per capita for country *i* in year *t*. It is the dependent variable, the variable we are trying to explain or predict through the regression model.

Exports_{it}, Imports_{it}, FDII_{it}, FDIO_{it}, GDP_growth_{it}, Inflation_{it}, Unemployment_{it}, Public_debt_{it}, Budget_deficit_{it} - the values of the independent variables for country *i* in year *t*.

ε_{it} - the term error or disturbance for country *i* in year *t*. This term captures all influences on GDP per capita that are not explained by the variables in the model.

u_{it} - the unit-specific effect or random effect, which captures the unobserved and time-constant characteristics of unit *i* that influence GDP_per_capita but are assumed to be uncorrelated with the independent variables.

Following regression with random models, the output is as follows (Table 4):

Table 4. Summary of regression analysis for the dependent variable GDP per capita (random effects)

Variable	Estimate	Std.Error	z.value	Pr
(Intercept)	9.58263219	0.10738418	89.2369	< 2.2e-16
Exports	0.01715008	0.00299053	5.7348	9.76E-09
Imports	-0.00457519	0.00364027	-1.2568	0.208816
FDII	-0.00067974	0.00060756	-1.1188	0.263223
FDIO	0.00206281	0.00075611	2.7282	0.006368
GDP_growth	-0.01608462	0.0034178	-4.7061	2.53E-06
Inflation	-0.03300691	0.00407356	-8.1027	5.37E-16
Unemployment	-0.05207606	0.00399563	-3.0332	< 2.2e-16
Public_debt	0.00336392	0.00076347	4.4061	1.05E-05
Budget_deficit	-0.01375562	0.00424787	-3.2382	0.001203
Total Sum of Squares	90.33			
Residual Sum of Squares	40.844			
R-Squared	0.54784			
Adj. R-Squared	0.54087			
Chisq	707.566 on 9 DF			
p-value	<2.22e-16			

Source. Eurostat & World Bank. The calculus was performed by the author with statistical software R.

Following the Hausman test - alternative hypothesis: one model is inconsistent - we chose the fixed effect model because we rejected the hypothesis that the floating effect model is appropriate for the dataset. The fixed-effect model also shows a relatively larger adjusted R-square, suggesting that it can explain a larger proportion of the variation of the dependent variable compared to the random-effect model.

Table 5. Hausman test results

chisq	60.346
df	9
p-value	1.15E-09

Source. The calculus was performed by the author with statistical software R.

After performing the Hausman test, we redid regression with fixed models, eliminating insignificant independent variables.

The specific multiple regression formula with fixed effects for statistically significant variables is as follows:

$$GDP_{per\,capita_{it}} = \alpha_i + 0.01934489 * Exports_{it} + 0.00169152 * FDIO_{it} - 0.01648328 * GDP_{growth_{it}} - 0.0300626 * Inflation_{it} - 0.04333717 * Unemployment_{it} - 0.01858312 * Budget_{deficit_{it}} + \varepsilon_{it} \quad (7)$$

where,

$GDP_{per\,capita_{it}}$ - the value of GDP per capita for country i in year t . It is the dependent variable, the variable we are trying to explain or predict through the regression model.

α_i - country fixed effect i . This is a unique constant for each country that captures all unobserved characteristics that do not change over time for that country.

$Exports_{it}$, $FDIO_{it}$, $GDP_{growth_{it}}$, $Inflation_{it}$, $Unemployment_{it}$, $Budget_{deficit_{it}}$ - the values of the independent variables for country i in year t .

ε_{it} - the term error or disturbance for country i in year t . This term captures all influences on GDP per capita that are not explained by the variables in the model.

Following regression with fixed models with significant independent variables, the output is as follows (Table 5).

Table 5. Summary of regression analysis for the dependent variable GDP per capita – for statistically significant variables (fixed models)

Variable	Estimate	Std.Error	t.value	Pr
Exports	0.01934489	0.00099957	19.3532	< 2.2e-16
FDIO	0.00169152	0.00041383	4.0874	5.00E-05
GDP_growth	-0.01648328	0.00302892	-5.442	7.89E-08
Inflation	-0.03006269	0.00364993	-8.2365	1.25E-15
Unemployment	-0.04333717	0.00329249	-13.1624	< 2.2e-16
Budget_deficit	-0.01858312	0.00381457	-4.8716	1.44E-06
Total Sum of Squares	80.856			
Residual Sum of Squares	32.105			
R-Squared	0.60293			
Adj. R-Squared	0.58028			
F-statistic	141.975 on 6 and 561 DF			
p-value	<2.22e-16			

Source. Eurostat & World Bank. The calculus was performed by the author with statistical software R.

The analysis revealed a significative relationship between dependent and independent variables, respectively GDP per capita and FDIO, export, the increase of PIB, unemployment, inflation, budgetary deficit. Also, the results obtained for R-square and adjusted R-square are 0,60293, respectively 0,58028. These combined with F-statistic, validate the model significance. These indicate that the model is significant, and independent variables assure a substantial explication of the observed variable.

Moving forward into analysing the regression analysis results, we can see that, the increase with 1% of the exports involve a 1.93% increase of PIB per capita. The extremely small value of statistical significance, indicates a very strong and direct relationship between exports and economic growth per capita, this aspect showing that states with oriented economies towards international trade benefit from economic growth through access to external markets. The significant connection between export and PIB per capita can be read also in the economic convergence key, through the fact that states that obtain economic performances by participating in the global trade can get closer in terms of PIB per capita.

Regarding foreign direct investments outflows (FDIO) investments, the 1% increase of them can determine a 0,17% increase of GDP per capita. Even if it's not as stonger as the exports, statistical significance shows though an important relationship between FDIO and PIB per capita, but this relationship reveals that foreign investments of national companies aboard contribute to internal economic growth, with direct influence over PIB per capita, respectively increasing of the living standards from the country of origin. Also, this type of investment highlights the companies importance that invest on international markets, these being powerful engines of economic development of the economies of those states.

The association between GDP growth rate and PIB per capita, where each percentual point of economic growth determines a PIB increase per capita with 1,65%, shows that economies with lower growth rates, grow faster than the ones with faster growth rates. The last ones experience a smaller growth according to absolute convergence hypothesis.

This reverse relationship suggests that, in regression models with fixed effect, the fast growth could come either the efficiency price of distribution per capita.

In the model above, a 1% increase in the inflation rate is associated with a 3% decrease in GDP per capita. This negative and statistically significant effect underscores the role of price stabilization in supporting per capita growth. For developing countries, controlling inflation is important for convergence because high inflation erodes real earnings and can hinder investment and consumption.

The negative effect against GDP per capita punctuate that volatility of the prices come with serious macroeconomic cost. High rate of inflation eat from purchasing power, affect the investments and/or consumption, all of them have a negative direct effect against economic performance. This result is compatible with specialized literature, that show the importance of stability of prices for a sustainability growth.

The increase in the unemployment rate by 1% is associated with a decrease in GDP per capita by 4.33%. This strong negative relationship underlines the importance of employment for economic growth. The significant negative impact of unemployment on GDP per capita reflects losses in output and efficiency associated with no utilization of labour. High unemployment may indicate structural problems in the economy, such as skills mismatches or labour market rigidities, which hamper economic adjustment and convergence.

An increase of 1% of the budgetary deficit it's related to a decrease of 1.86% of PIB per capita, which suggested that the massive deficits can have a negative effect over the increase per capita. Fiscal disciplines, especially in the context of economic convergence, are essential.

The emerging economy countries may have sustainable economic growth and may close the gap in development with developed countries, by keeping the government expenditure within reasonable limits. Prudent public financial management allows for a better investment policy and may prevent or limit public debt growth, aspects which would clearly contribute to generating an investment friendly economic environment, increase of living standard thus contributing to accelerating convergence.

At the moment, following the results of the regression analysis, when we examine the impact of exports and FDIO (foreign direct investment outflow) on economic growth, it is essential to refer to the dependent variable, GDP per capita, in order to understand how these external economic flows contribute to per capita convergence between EU member countries. Outward orientation, evidenced by exports and FDIO (foreign direct investment outflow), can boost per capita GDP growth by providing the means by which local economies integrate into global chains, benefit from technology transfer, and improve their economic efficiency.

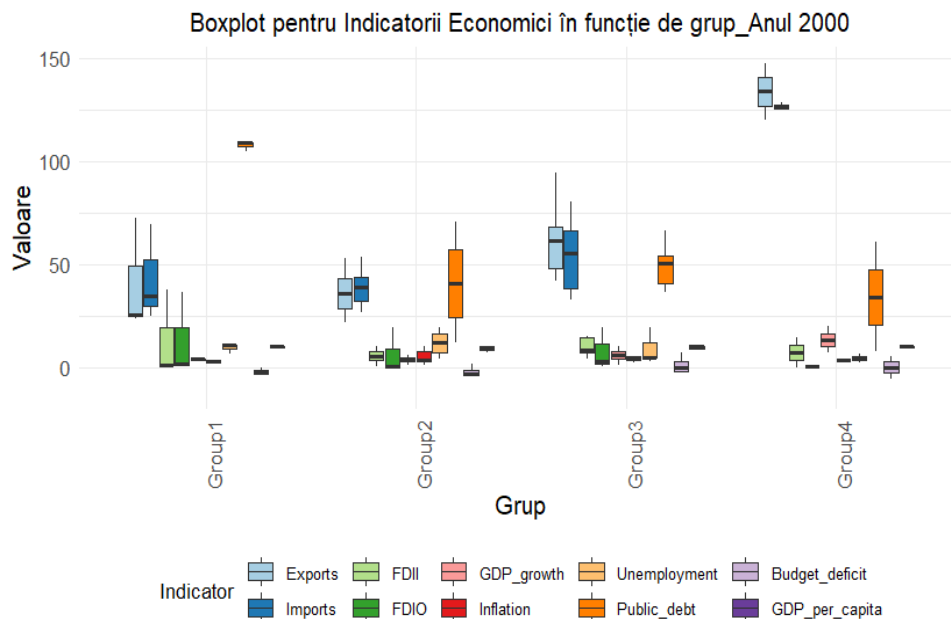
These ways are more important for emergent economies in order to catch and to align with the development countries.

Likewise, the presence of a negative coefficient for GDP growth in the analysis indicates that as economies approach the technological and efficiency frontiers, per capita GDP growth rates may begin to decline, aligning with convergence theory. This suggests that while developing countries may initially experience rapid growth in GDP per capita due to integration and globalization, these growth rates may moderate as income differences with more advanced countries are reduced.

Regarding macroeconomic stability, the analysis connects high inflation and unemployment, along with big financial deficit, with negative effects of PIB per capita. Macroeconomic stability is essential for the sustainability of economic convergence. High inflation and unemployment can undermine the basis of per capita growth by eroding purchasing power, while an excessive budget deficit can reflect unsustainable fiscal policies that can ultimately affect long-term economic growth and the ability to converge.

Following the segmentation of countries based on a prior cluster analysis, which grouped states according to their similar economic characteristics, it is imperative to deepen the understanding of internal dynamics and differences between these formed groups. Therefore, by applying the ANOVA analysis we identified the significant economic performance differences that could highlight diverging trajectories or convergence in their own development.

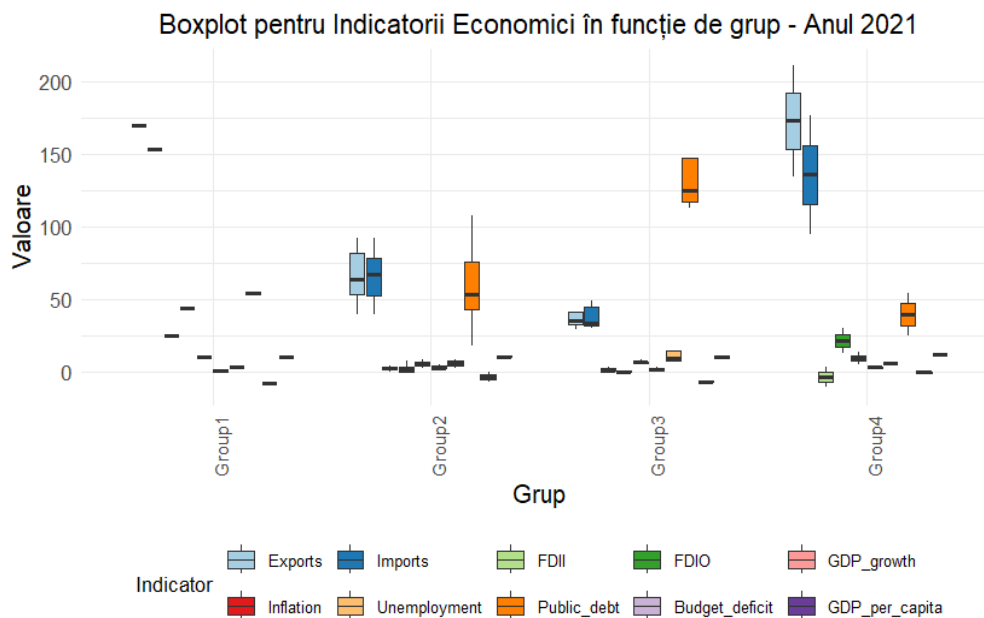
Following ANOVA's analysis, the results suggest that in 2000 there were significant differences in trade performance and public debt levels between groups, while for foreign investment, inflation, unemployment, budget deficit and GDP per capita there were no significant differences between them.



Graph 7. Distribution of indicators by group (year 2000)

Source: Eurostat & World Bank. The data was processed by the author with statistical software R.

On the other hand, the ANOVA analysis for 2021 reveals that, together with comparisons with previous years, highlights that the convergence process between EU27 countries is not uniform and that there are still divergences in certain economic indicators. Differences can be influenced by economic policies, economic structures, major economic events, and other factors.



Graph 8. Distribution of indicators by group (year 2000)

Source: Eurostat & World Bank. The data was processed by the author with statistical software R.

Following ANOVA's analysis, the overall conclusion is that the process of economic convergence is not linear or uniform.

The differences resulted following the calculations may indicate that even though economic integration provides many opportunities, it brings along also important challenges for the member states. Adaptability and cooperation may be the adequate response to facing these issues.

Conclusion

The economic convergence analysis in the European Union shows a detailed image of the way member state act regarding economic integration și economic performance. The diversified range of economic indicators that are at the base of this analysis offer comprehensive image of economic environment of European Union, and also its progress towards equal economic levels. The image of the last years reveals trends through the appearance of an economic solidarity, and also an increased capacity to handle financial shocks.

The analysis indicators, such as exports, direct foreign investments, PIB growth, inflation, unemployment or budgetary deficits together sketches out a more detailed economic image of the European Union. After we present in the study, the increase of the exports correlates very seriously with the PIB growth per capita, which represents the benefits of a deeper integration in the global commercial system, respectively the positive impact of employment of states in the international commercial system. Besides the commitment and opening towards international trade, direct foreign investments inflow (FDII) plays a very important role in economic development.

The connection between the increase of value of exports and domestic economic growth represents a very important element in order to understand dynamic of economic convergence. That shows as good as has integrated the member states into commercial global chains or how good the economy is. Even if, a series of experts indicate that economic convergence process is already in progress, is a historical process, the analyses confirm that, but point that economic challenges that there are between member states.

These disparities are reflected in the different levels of economic performance, driven by structural differences, national policy decisions, access to resources, technology and/or the ability of economies to respond positively to external shocks. For example, while some states show robust growth, others struggle to keep up, hampered by less favourable economic structures or policy frameworks. Nevertheless, the present study reveals that a very fast economic increase can damage the distribution of the resources. Rapid economic expansion can sometimes lead to unequal benefits if certain regions or sectors disproportionately win, exacerbating income inequality. Identically, high inflation or unemployment rates directly affect living standards, reducing purchasing power or increasing economic insecurity among citizens.

The general conclusion is that balanced, calibrated macroeconomic policies that are specific to each Member State are needed, structural and economic changes must be made gradually, so that the countries that want to reach the highest level have a healthy growth on a solid basis. Only in this way will disparities between states disappear in a natural and healthy way, and the new structures be capable, this approach will strengthen the economic structure of individual nations, as well as the collective resilience and prosperity of the EU as a whole.

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