SPATIAL ANALYSIS OF REGIONAL INCOME INEQUALITY IN EU COUNTRIES

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Abstract

Research on regional convergence deals with the question of whether regional disparities are decreasing over time. This article investigates regional income inequality in the EU27 over the period 2000-2019, with the aim of assessing the spatial impact of income fluctuations on regional inequality. Empirically, we draw on quantitative secondary analysis of income per capita indicators among NUTS 3 level regions and their evaluation over time. The article contributes to the burgeoning research on economic convergence in the EU in the following ways: first, it provides an assessment of regional income inequality in the EU, encompassing the most prevalent instruments used in the analysis of inequality data; second, it determines EU regional disparities at NUTS 3 level, using constructed Theil, Gini and CV indices exposing a more comprehensive evaluation of regional disparities within the EU; and, third, it examines the nexus between spatial effects on regional income inequality. Our findings indicate that at NUTS 3 level, convergence in the EU still exists, but its speed is slowing down. We also point to the role of clustering effects among neighboring regions. Overall, regional clustering due to income inequality is decreasing along with the convergence process.

Keywords: Regional inequality, Economic convergence, Spatial autocorrelation, EU27
JEL classification: O47, C21, R11

1. Introduction

By the beginning of the twenty-first century, the issue of regional income inequality had become one of the most critical topics in economic and political debates (e.g. Tselios et al. 2012; Tammaru et al. 2022). Within the EU such debates intensified due to the EU's eastward enlargement encouraging a 'catch-up' process for new EU members (Fredriksen 2012). In fact, the results of regional income inequality studies over this period (e.g. López-Villuendas and del Campo 2023; Butkus et al. 2018; Giannakis and Bruggeman 2020) suggest that there was a trend towards absolute income inequality in the EU. These studies also reveal a conundrum: convergence occurs at the national rather than the regional level; that is, differences in per capita GDP between countries have decreased, while differences within countries have largely stagnated or even increased (Giannakis and Bruggeman 2020; Butkus et al. 2018). Obviously, one of the important reasons to measure regional inequality is to examine the effectiveness of the European Cohesion Policy (Becker, Egger and Von Ehrlich 2012). Furthermore, balanced regional development and tackling regional disparities has constituted and still remains a key policy ambition within European planning visions (Kunzmann, 1996; Davoudi 2003; Schindler and Kanai 2021).

Despite the interest on the issue of regional income inequality, the sub-national level has drawn less attention as most of research focuses on inequality problems in the EU at the NUTS 2 level (e.g. Stanickova and Melecký 2018; Lipps and Schraff 2021). At the NUTS 3 level, this phenomenon is mostly researched in southern and central-eastern European countries (e.g. Arbia, Basile, and Salvatore 2003; Eczurra et al. 2007; Scott 2016; Bourdin 2015), while older EU member states receive less attention (Geppert and Stephan 2008). Furthermore, during the last decade, researchers started to use spatial analysis in regional income inequality, but mostly done on a small scale (Gezici and Hewings 2007; Khan and Siddique 2021). In this context, we aim to analyze the spatial effect on regional inequality at the sub-national level in EU countries, with a particular focus on showing how spatial interactions effect the income of the regions.

There has been a renewed interest in regional inequalities as new developments in methodology have opened the way to more creative considerations (for example: Panzera and Postiglione 2022; Butkus et al. 2018; López-Villuendas and del Campo 2023). Such new methodologies include using different indices to address the income inequality problem in the same case study (Butkus et al. 2018), comparison of regional income inequality in different spatial scales such as NUTS 2 and NUTS 3 (López-Villuendas and del Campo 2023), and integration of spatial analysis and income inequality indices (Gezici and Hewings 2007). By examining the regional characteristics of the different parts of a country, it was observed that spatial interaction and geographical location play an important role in explaining regional economic performance (Gezici and Hewings 2007). The inequality literature had generally neglected the spatial dimension (Rey 2004), although in more recent years many contributions have addressed such geographies of inequality (Rodríguez-Pose and Storper 2020; Xin-gang and Fan 2019). In particular, economies of scale, agglomeration of human capital, institutional framework, and geographical structures of certain regions accrue economic rents to be more local (Martin and Sunley 1998; Yıldırım and Öcal 2006). Studies have also revealed that economic inequality within specific case studies is higher than the inequality observed at the country level (R.J. Barro et al. 1991; Azzoni 2001; Terrasi 1999; Pekkala 1999; Yıldırım and Öcal 2006; Kitsos, Carrascal-Incera, and Ortega-Argilés 2019). Our study contributes to this literature, because we didn't just use income inequality indices and spatial interaction to see the clustering in the EU27, but we also added relative income maps to support our findings and to show how inequality fluctuations effect income across regions.

Reducing regional inequality has been a critical mission of the economic policy of the EU (Le Gallo, Ertur, and Baumont 2003). The EU as a whole has north and south spatial regimes (Le Gallo and Ertur 2003), while such divisions are also evident within member states. Italy for example is still characterized by historical north and south dualism (Terrasi 1999; González 2011; Felice 2018). Greece has been characteristically divided too, creating the narrative of two regions, Athens and non-Athens (Siriopoulos and Asteriou 1998), although regional convergence is reported in more recent years (Petrakos and Saratsis 2000; Stanickova and Melecký 2018). Such regional imbalances make it vital to analyze the spatial effect on NUTS 3 regions as a whole. Although there have been earlier studies on this(Gezici and Hewings 2007; Ezcurra and Pascual 2007), emphasis on cross-country regional inequalities are less common when compared to studies at the national level.

In this context, our goal in this paper is threefold. *First*, we assess regional income inequality in the EU, encompassing the most common instruments used in the analysis of inequality as well as up-to-dated data. *Second*, to determine EU27 regional disparities at NUTS 3 level, using constructed Theil, Gini and CV indices exposing a more comprehensive evolution of regional disparities within the EU, as well as using GDP (EUR per capita) in NUTS 3 regions over the 2000–2019 period. We note that we used the Gini index with a different perspective than usually, i.e. without involving the Lorenz curve. Third, we examine the nexus between spatial effects on regional income inequality using Local and Global Moran's I. The combination of our indices and the spatial dimensions of relative income we have used not just analyzes the regional clustering of GDP, but also the distribution of GDP and how it is influenced by the spatial location of the regions irrespective the countries they are based. The point here is that we want to see whether the GDP distribution in the EU is limited within the country level or influenced by the neighboring regions from other countries.

The rest of the paper is organized as follows. The following section (2) provides a brief theoretical introduction to regional income inequality along with some empirical studies and a summary of recent critical studies of EU convergence at the NUTS 3 level. Section (3) introduces the inequality indices, specifically the Theil, Gini and CV indices; following that, attention is directed to spatial dependence, global and local clustering, using Moran's I and Anselin indices. Section (4) emphasizes the dynamics of disparities in the EU at the NUTS 3 level and presents the main findings emerging from our secondary analysis. From 2000–2019, the spatial pattern of gross domestic product (GDP) regional growth is examined with their initial level of GDP per capita. Finally, conclusions are discussed in section (5).

2. Regional inequality

Different research techniques have been employed to assess the EU's process of convergence. Neoclassical growth theory is the foundation for studies looking at the so-called β-convergence process (Solow 1956; Koopmans 1963). Another important contribution in this area was by Barro and Sala-i-Martin (1991) who reintroduced mainstream macroeconomics to the concept of region. This contribution sparked an explosion of research on the question of regional economic convergence (Durlauf and Quah 1999; R.J. Barro et al. 1991). Much of this research represented a shift in focus from studying the dynamics of international income disparities to analyzing intranational dynamics. That is, whether incomes between regions within a given nation-state become more or less similar over time (Rey 2004). Barro and Sala-i-Martin claim that β-convergence is shown when all regions are approaching the same level of steady state. According to Barro and Sala-i-Martin, the process of convergence among EU nations was comparable to that in the US, and progresses at a rate of roughly 2% each year (R.J. Barro et al. 1991). Other early studies showed β-convergence among EU nations with slow convergence rates (Cuadrado-Roura 2001; Cappelen et al. 2003). The estimated convergence indicators were quite erratic and exhibited reversible signs. For a number of reasons, the neoclassical theory of convergence has been being criticized. First, alternate models are rarely used when testing it (Magrini 1999). Second, β-convergence might be influenced by factor mobility and other uncontrollable variables (Fingleton 1999). Third, due to the stark differences in the initial conditions across the regions, absolute convergence is indicated. More recent studies (e.g. Kim 2012; Guerreiro and Guerreiro 2015; Chocholatá and Furková 2017; Rego and Caleiro 2009) considered R&D expenditure as an important key factor for regional convergence or divergence tendencies.

The σ-convergence method, which refers to a declining distribution of income among economies, is another contribution from Barro and Sala-i-Martin (R. Barro and Sala-i-Martin 2004). However, studies using this methodology have produced inconsistent results: while some studies (Boldrin and Canova 2001; Yin, Zestos, and Michelis 2003) find evidence of σ-convergence in the EU, other studies do not support this theory (e.g. Neven and Gouymte 1995; Basile, De Nardis, and Girardi 2001).

The third idea of convergence, known as 'club convergence', is used to determine if groups of essentially homogeneous regions converge to a comparable steady-state value within the group, but differ between groups. The idea of club convergence was introduced by Baumol

(1986). Compared to standard convergence analysis, the analysis of convergence clubs paints a more accurate and thorough picture of regional income growth. Borsi and Metiu (2015) found four convergence clubs when analyzing data on the EU27. They stated that convergence clubs are formed based on geographic regions, but are not related to membership in the Eurozone. Von Lyncker and Thoennessen (2017) confirmed club convergence in the EU15; for them, Northern, Central, and Southern Europe's income growth paths differ significantly, demonstrating a multispeed EU along with geographic regions.

The study of regional inequality offers interesting contrasts and similarities with the literature on regional convergence. Regional income inequality analysis has its origins in the study of personal income inequality. The latter is a numerical scalar representation of the interpersonal differences in income within a given population (Cowell and Jenkins 1995). Income inequality is most notably measured using the distribution of income or GDP per capita, the distribution of wealth. Besides income inequality between nation-states, there is essential economic inequality between different groups of people. Important types of economic measurements focus on wealth, income and consumption.

Several factors are involved in the explanation of regional inequality within a nation. These include the growth of the labor force, capital stock, and technological progress. The growth of GDP has always been used as an essential measure for analyzing regional inequalities (Gezici and Hewings 2007).

Despite the rich geographical dimensions underlying the data used in regional income convergence analysis, the importance of spatial effects gradually begun to attract attention (see some early contributions: Vickerman and Armstrong 1995; Fingleton 1999; Chatterji and Dewhurst 1996; and more recently: Khan and Siddique 2021; Panzera and Postiglione 2020, 2022). Spatial dependence occurs when the values for a phenomenon measured at one location are associated with those measured at other locations (Anselin 1988). The issues that spatial dependence raises for econometric analysis of regional income convergence have received attention from early on (Fingleton 1999; Rey and Montouri 1999). However, the role of spatial dependence in regional inequality studies has been less explored (although see some exceptions: Khan and Siddique 2021; Panzera and Postiglione 2022; Eva et al. 2022). The issues associated with spatial dependence may be conveniently split into two groups. From a substantive perspective, spatial dependence can play an essential role in shaping the geographical distribution of incomes. From a nuisance perspective, spatial dependence can complicate the application of traditional statistical methods designed to analyze regional inequality (Rey 2004).

Empirical studies on regional inequalities have focused on interregional and intraregional inequalities using the Theil Index (Terrasi 1999; Petrakos and Saratsis 2000; Fujita and Hu 2001; Liu 2006; Gezici and Hewings 2007; Butkus et al. 2018). These studies used different decompositions, such as interprovincial, coastal, and interior. Furthermore, Rey's (2004) analysis of the spatial effect on regional inequality in US regions evidences a strong positive relationship between the measure of inequality in state incomes and the degree of spatial autocorrelation. Fan and Casetti's (1994) analysis of the spatial and temporal dynamics of the US regional income inequality found that during polarization, income inequality between states in the traditional core is low, and income inequality between them and the peripheral states is high. In the EU, Petrakos' research on growth, integration and regional inequality demonstrates that those disparities at the national and the EU27 levels exhibit procyclical behavior in the short-term, increasing in periods of growth and decreasing in periods of slow growth (Petrakos, Rodríguez-Pose, and Rovolis 2003). Gezici and Hewings' (2007) study on regional inequality in Turkey, provides an opportunity to view the inequalities and interdependence among regions in terms of spatial aspects. The impacts of developed provinces/regions have to be considered with their spillover effects on their nearest neighbors and their contribution to the overall inequalities (Gezici and Hewings 2007). Table 1 summarizes some of the most important empirical studies of convergence and spatial dependency in the EU at the NUTS 3 level.

Table 1. Summary of empirical studies of convergence in the EU at NUTS 3 level

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As Table 1 indicates, there are some published studies covering most of the EU regions at the NUTS 3 level [specifically the articles 1, 6-11, 9 and 15], but there is no research that includes all NUTS 3 regions in the EU27. Furthermore, there is no empirical study about spatial autocorrelation that includes all NUTS 3 regions. We understand that cross-national analysis using regional classifications such as NUTS 3 has weaknesses, as they don't always correspond to functional and identifiable regions (see also Casellas and Galley 1999); however, this is a level of analysis commonly used in similar research (López-Villuendas and del Campo 2023; Panzera and Postiglione 2022) given the lack of other data across the EU to investigate regional income inequalities. In terms of geographical coverage, the existing research has examined only newer EU members (see Artelaris, Kallioras, and Petrakos 2010) and mainly southern and central eastern European regions (Kostakis and Theodoropoulou 2017; Ezcurra and Pascual 2007). The majority of empirical investigations on convergence/divergence processes drew on statistical or econometric models with a linear specification (e.g., Panzera and Postiglione 2020, 2022; Stanickova and Melecký 2018). In summary, most studies confirm the EU's convergence. However, the analysis of convergence at the NUTS 3 level shows a different story: disparities decreased at the national (state) level but not at the regional level, and the speed of convergence varies over time. The outcomes of the empirical researches vary, mostly depending on the method used, the number of regions surveyed, and the period covered. In this context, this paper aims to explore income inequality in NUTS 3, using the most recent data published by Eurostat. We have therefore tried to understand the nexus between spatial effect and income inequality at the NUTS 3 level. Relative income is another essential part of our research which we used to map GDP changes between 2000-2019. By integrating these three methods of analysis, we describe different aspects of income disparities and geographical elements.

3. Methodology and data

The paper draws on secondary analysis of EU public data meansuring convergence. The task is challenging for two main reasons: first, even though they are connected, different conceptions of convergence refer to different elements of the same process; therefore, it is important to consider what exactly each convergence indicator is measuring. And, secondly, it is vital to keep in mind the limitations of the current indices and to study convergence in the EU using multiple approaches and methodologies. There is no index to quantify convergence that would allow to capture all features of this phenomenon.

σ-Convergence and spatial autocorrelation are the main focuses of this section; the former refers to the decrease of disparities between regions over time, while the latter shows the spatial correlation of the income inequality of the regions. The primary source of data for this study is the Gross Domestic Product (EUR per capita) at current market prices by NUTS 3 regions. Information on population and per capita GDP is accessible in the Eurostat data sources up to 2019. The Nomenclature of Territorial Units for Statistics (NUTS) provides a system for procuding regional statistics across the EU. According to NUTS 2010 codes (the NUTS nomenclature divides the territories of the European Union into 97 regions at NUTS 1, 270 regions at NUTS 2, and 1,294 regions at NUTS 3), our data was gathered from regional and local sources of information corresponding to NUTS 3 which have a population range between 150,000 and 800,000 people. NUTS 3 refers to the smallest categories in NUTS 2010 codes which contains small regions. In total 1,169 NUTS 3 regions area were examined over the 2000–2019 period (20 years), which was chosen on the basis of data availability, and because it also demonstrates the effect the global financial crisis had on the EU. The regional GDP time series has been constructed from European statistics.

According to Table 2, the regions with GDP per capita higher than the average GDP per capita have decreased from 50.90% in 2000 to 46.45% in 2019. Also, there is a big difference between maximum and minimum GDP in all years. Furthermore, Table 2 demonstrates that the standard deviation increased significantly in 2019, showing that the GDP per capita started to spread across the regions. The minimum GDP in 2000 and 2019 belongs to Vaslui, Romania with 800 and 4,000 EUR per inhabitat, the maximum in 2000 and 2019 GDP belongs to Wolfsborg, Germany with 84,200 and 19,1900 EUR per inhabitat. These regions stand out because the highest GDP region (Wolfsburg) is one of the largest regions of Germany, and most of the car production factories are located there; on the contrary, in terms of the lowest GDP (Vaslui), this is one of the smallest regions in Romania.

Table 2. Data

[INSERT]

3.1. Income disparities

Regarding our analysis, we acknowledge that there are many indices for income inequality in the literature. This paper covers Theil, Gini and the coefficient of variation to measure inequality in the EU27. All 3 indices are calculated by writing the code of each index equation in the R programming language. This section explains these indices and the equations used in our paper. First, the regional income inequality indices are used to show the convergence trends between NUTS 3 regions. Then, we will look at the spatial interactions of NUTS 3 using Global and Local Moran's I. Finally, we will look at the relative income, which we utilised to show how spatial interactions affect the GDP (EUR per capita).

3.1.1. Theil index

One of the most widely used indices in regional inequality analysis has been Theil's inequality measurement (Theil 1996). Theil equation (Rey 2004) (1) is given as:

$$T = \sum_{i=1}^{n} S_i \log(nS_i) \tag{1}$$

Where n is the number of regions, y_i is per capita income in region i. Si (relative income of the region i) is calculated based on equation (2):

$$S_i = \frac{y_i}{\sum_{i=}^{n} y_i} \tag{2}$$

In equation (1), T is bounded on the interval [0, log(n)] with 0 reflecting perfect equality, and log(n) occuring when all the income is concentrated in one region.

3.1.2. Gini Index

The Gini index is calculated using equation (3):

$$G = \frac{2\sum_{i=1}^{n} i y_i}{n\sum_{i=1}^{n} y_i} - \frac{n+1}{n} \tag{3}$$

In the equation (3) for a population uniform on the value y_i, i represents the number of the regions indexed in non-decreasing order ($y_i \leq y_{i+1}$). The equation (3) can be applied to calculate the Gini coefficient without direct reference to the Lorenz curve. Gini measures income distribution or, less commonly, wealth distribution among a population (Gini 1912). The coefficient ranges from 0 (or 0%) to 1 (or 100%), with 0 representing perfect equality and 1 representing perfect inequality.

3.1.3. The Coefficient of Variation (CV)

The coefficient of variation is used to measure inequality using formulation (4). It shows the variability in relation to the mean of the dataset. It ranges between 0 and 1.

$$C_v = \frac{\sigma}{\mu} \tag{4}$$

3.2. Spatial autocorrelation

Spatial autocorrelation is the process whereby entities at different points in physical space make contacts, demand/supply decisions or locational choices (Roy and Thill 2003). It is analyzed based on two indices, Global and Local Moran's I. Moran's I provide an indicator for spatial autocorrelation, here interpreted to imply value similarity with locational similarity. A positive autocorrelation occurs when similar values for the random variable are clustered together in space and vice versa (Cliff et al. 1981; Upton and Fingleton 1985). The spatial dependence (global spatial autocorrelation) measure of Moran's I is represented by the equation (5):

$$I_i = \frac{n}{s} \frac{\sum_i \sum_j w_{ij} z_i z_j}{\sum z_i^2} \tag{5}$$

In the (5) equation, n is the number of regions, Z_i and Z_j are the deviation of the log of per capita income from the mean of each region, W_{ij} are the elements of weight matrix w ($n \times n$), and the weight (W_{ij}) is equal to 1 if regions i and j have the same borders and 0 if they don't; s is the sum of all elements of W (spatial weights). A value of Moran's I around 1 represents strong and positive spatial autocorrelation, while values around -1 show negative spatial autocorrelation, and 0 represents that there is no spatial autocorrelation.

Anselin (1995), suggested a new index for spatial dependence called Local Moran's I or LISA statistics. Local Moran's I is calculated using the equation (6). It has two basic functions: first, they assist in identifying spatial clustering; secondly, it can be used to diagnose local spatial outliers in measures of global spatial association.

$$I_i = z_j \sum_j^n w_{ij} z_j \tag{6}$$

The observations Z_i, Z_j Are the deviations from the mean, and the summation over j is such that only neighboring values are included (Anselin 1995). The Local Moran's I statistic enables the identification of both positive and negative types of spatial interactions.

3.3. Relative income

The relative income (RI) hypothesis was proposed by Duesenberry (1949) to explain patterns of consumer behavior. The relative income hypothesis states that individual utility depends on income which is relative not only to their own absolute income but to others' income (Brown, Gray, and Roberts 2015). In this paper, each region's relative income is calculated by dividing its GDP per capita in the initiated year by the mean GDP per capita of whole regions.

4. <u>Results</u>

This section presents an inequality analysis where inequality indicators are calculated and their evolution over time is investigated. The regional inequality studies claim that the growth process of regions is similar to that of national states, mainly due to free capital and labor mobility compared to the international level (Yıldırım and Öcal 2006). We examine below regional inequality by using the three different inequality indices in 1,169 regions (EU27) over a 20-year period. Attention is first directed towards regional income inequality and spatial dependence; then, we describe the relationship between these two.

4.1. Regional income inequality

It is observed from Figure 1 that total inequality, according to the Theil index, decreased from 2000 until 2008. After that, the inequality in EU27 countries started to increase slightly; although the inequality in 2019 was lower than the inequality in 2000, the minimum inequality that EU27 countries had was in 2008. The interval in our study for the Theil index is between 0 and 0.328. In 2019 the Theil index was 0.144; this shows that inequality in the EU27 countries declined by 2019.

Figure 1: Theil Index

[INSERT]

Figure 2: COV Index

[INSERT]

Convergence among EU countries took place until 2008, but since then, this tendency has stopped. This is observed in other studies too (López-Villuendas and del Campo 2023; Butkus et al. 2018). According to Figure 3, from 2000-2008, the dynamic of regional income disparities among EU countries showed a clear downward trend as the coefficient of variation decreased from 0.613 to 0.536. On the contrary, since 2008, it started to increase, and in 2019 it was already 0.568. This change does not seem to be huge, but divergence was persistent from 2008. Initial divergence in 2000 changed to nonpersistent convergence lasting until 2008 and once again turned to divergence since 2009. Over the 20 year period, disparities decreased by 6.3%.

Figure 3: Gini Index

[INSERT]

While assessing the discussed evolution of EU disparities, the fact that CV is more sensitive to changes in the upper end of the distribution (i.e., the changes that are taking place in relatively more developed regions in terms of per capita GDP) should be considered. Another index that was utilized in our research of σ-convergence in the EU is the Gini coefficient. Although this index is the most commonly used for measuring personal income or wealth inequality, it is not without drawbacks (Panzera and Postiglione 2020). For example, it is affected by the granularity of the measurements; that is, calculations based on low granularity would probably output a lower Gini coefficient compared to one based on high granularity taken from the same distribution. In Figure 3, disparities in the EU at the NUTS 3 level declined from 0.325 in 2000 to 0.288 in 2019. Most of this decrease, however, was until 2008, when the Gini index had its lowest value (0.282). Later, changes in the disparities were rather mixed with no clear trend. This is in line with our CV analysis, showing that convergence between countries is stagnating. It can be observed that the total inequality was declining until 2019.

In Figure 4, it can be observed from all three indices that 2008 was a critical year for EU countries, marking also the impact of the global financial crisis and subsequently the European debt crisis (Folfas 2016). All three indices showed that the total inequality decreased until 2008, and the inequality in 2008 was at its minimum. After that, inequality started to increase until 2015; after that, it started to decrease again but never reached the minimum point that inequality had in 2008.

Figure 4: Inequality Indices

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Overall, the inequality analysis indicated that income inequality has a procyclical nature in EU27 in the time period under consideration, which raises an important question concerning the relationship between regional inequalities and economic performance. Moreover, even though the overall income inequality decreased, regional disparities are observed. Having analyzed four indicators of σ-convergence over 20 years, we summarise our main findings about the evolution of the disparities in the EU below:

- The clear evidence of convergence between territories at the NUTS 3 level was just for the period 2000–2008, with rather mixed results for the periods before and after that;
- The disparities become sharper and convergence less clear as we analyze smaller territorial units;
- For the period when convergence was detected, it was mainly present due to poor territories becoming richer, for the period when divergence was detected, it was present not just due to poor regions becoming even poorer, but also due to richer regions becoming even richer.

4.2. Spatial autocorrolation

Figure 5 portrays the spatial effect on GDP per capita in EU27 regions. The long-term trend has been declining using the Global Moran's I. It was observed that between 2000 and 2019, Moran's I index decreased. This shows a positive relationship between income inequality and spatial autocorrelation of GDP in the EU member states. Figure 6 indicates that 368 out of 1,169 regions were significant. There were 110 HH (number of high-income regions sharing a border with another high-income region), 249 LL (number of low-income regions sharing a border with another low-income region), and 9 regions were either neighboring a region with high income (H) although they had low income (L) or the opposite.

Figure 5: Moran's Index

[INSERT]

Figure 6: Clustering Map in 2000

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Figure 7 shows spatial autocorrelation in 2008, the year that EU27 had the least income inequality. In 2008 there were 96 HH, 243 LL, and 21 regions that are either neighbors of regions with H income although they had L income or the opposite.

Figure 7: Clustering Map in 2008

[INSERT]

Spatial autocorrelation in 2019 is shown in Figure 8. In 2019, HH regions increased to 104; LL regions increased to 262, and the regions that either there are neighbors with H income although they had L income or opposite decreased to 17.

Figure 8: Clustering Map in 2019

[INSERT]

By comparing local Moran's I and regional income inequality in the examined period, it is observed that the clustering decreased in 2008, which shows that when regional inequality decreases, it affects the clustering. Table 3 shows that when regional inequality decreases, Morans's I also decrease. This demonstrates that regional inequality and clustering have a strong relationship.

Table 3: Indices

[INSERT]

In Figure 9, the kernel density graph shows that the relative income in EU27 shifted up between 2000 and 2019. In regions with a high income, their GDP per capita increases. It shows that the highest value for the kernel density graph in 2000 was 0.84, which increased to 0.93 in 2019.

Figure 9: Kernel density graph

[INSERT]

When we examine the relative income maps discretely in 2000 and 2019, we find that some of the very high-income regions become low and some low-income regions become a region with high income (Figures 10 and 11). This shows that regions' income changed in 2019; also, according to Table 2, the regions with income higher than average decreased, and that's the reason some regions' income in Figures 10 and 11 changed between 2000 and 2019. Most of the rich regions are located in the center and northern part of the EU, and most of the eastern countries have low incomes.

Figure 10: Relative Income in 2000

[INSERT]

Figure 11: Relative Income in 2019

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5. Conclusion

In this study, regional inequality in the EU was measured by using three different indices. Our results show that there was convergence until the global financial crisis of 2008 and divergence after 2008; also, spatial autocorrelation was analyzed using Global and Local Moran's I statistics. This revealed a positive relationship between regional inequality and spatial autocorrelation. Overall, our analysis shows that inequality decreases until 2008 and reaches its minimum, then increases until 2016, then declines until 2019. Local Moran's I also showed almost the same clustering trend along with inequality.

Regional disparities are an important issue in EU members' economic policies. Our graphs provide further evidence that EU as a whole has two broadly different regimes, east, and west (see also: Kotosz and Lengyel 2017; Bourdin 2015; Kostakis and Theodoropoulou 2017). Low-income countries appear to be clustered on the east side of the EU, while the countries on the west side have high incomes. This causes regional inequality in EU countries. Also, it was observed that the spatial dimension affects regional inequality. Our results show that regions with equally distributed income mostly have a border with each other and are clustered in the center of Europe. As there was convergence in EU regions until 2008, but divergence after 2008, we can speculate that the European debt crisis played a significant effect on convergence.

Our findings provide an opportunity to view the regional inequalities in terms of spatial aspects. Regarding regional income inequality, our results align with other studies (e.g. López-Villuendas and del Campo 2023; Butkus et al. 2018); in terms of the spatial dimension, we observed that regional income inequality has a positive relationship with clustering, similar to Gezici and Hewings (2007). In terms of EU27, we observed that there is clustering in Europe's east (low-income regions) and center (high-income regions). The impacts of unequally developed regions and countries have to be considered in relation to their spillover effects on their nearest neighbors and the contribution they make to the overall inequalities. Our findings suggest that the economic performance of western regions have led to the regional development of the other EU countries and they have influenced positively their nearby regions. However, the regions that show negative spatial autocorrelation should also be considered for policies that change their relationship with their neighbour. Regional policies need to be sensitive to the impacts of different definitons used for regions on their outcomes (Iammarino et al. 2019). Different types of regional policies may have different impacts on regional inequalities. Considering that government expenditures are the main instrument to address income inequality and the impact of the individual countries on the EU27 whole economy, it appears that any crisis that happens in any country impacts the whole system. This suggests the need for strong monitoring and coordination of EU27 countries to prevent crises similar to the more recent European financial crisis (André et al. 2009). The analysis of this study which was based on data from NUTS 3 regions, investigates the spatial effects of income inequality between regions in EU27. It will be important to review the findings of this paper and thus place regional development issues into a broader international context that looks the effects of income inequality on regional development policies to neighbourhood countries.

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6. Tables

Table 4. Summary of empirical studies of convergence in the EU at NUTS 3 level

Research	Analysis Period	Method	Research Sample	Result
Butkus et al. (2018) (1)	1995-2014	Theil, Gini, CV, and MLD	EU NUTS 3 and 2	Convergence at national level and divergence at national level
Artelaris, Kallioras, and Petrakos (2010) (2)	1990–2005	Coefficient of variation	New Member States of European Nation	Regional convergence clubs were identified in Numerous of the new EU member states
Bourdin (2015) (3)	1995–2007	Gini index	Regions of Central and Eastern Europe	Convergence was found at a national level, but income inequalities within each country were increasing
Scott (2016) (4)	2000–2013	Moran's I for spatial autocorrelation	238 regions of CEE	The chance for convergence is higher at the national level than at the regional level
Braga (2003) (5)	1970–2001	β-convergence estimated using nonlinear least squares	Portuguese regions	The clustering phenomenon affects the growth and convergence both within and between regions
López-Villuendas and del Campo (2023)(6)	2000-2017	time-series clustering analysis	EU27 NUTS 3	Finer spatial scale inequality in period of 2008 crisis and after, clustering at NUTS 2 and 3
Kramar (2015) (7)	2000–2011	Coefficient of variation	EU28 1090 regions	Rural areas are lagging behind urban areas economically, yet there is a growing disparity between them. However, there is no evidence that the degree of divergence is greater in the countries with the quickest growth rates
Cardoso and Pentecost (2011) (8)	1991-2008	β-convergence via Applying shift-share analysis, which enables the breakdown of the deviation of a region's output growth rate	Portuguese regions	On regional expansion and convergence, human capital has a significant and positive impact
Gagliardi and Percoco (2017) (9)	2000-2006	RDD for regression discontinuity and LATE for local average treatment impact	1233 EU25 regions	European Cohesion funds positively impacted the growth of underdeveloped rural regions
Mikulić, Lovrinčević, and Nagyszombaty (2013) (10)	2001–2008	β-convergence estimated using the common cross-sectional OLS approach	EU27 and Croatia	Absolute β-convergence happens at the national level for NMS areas and EU countries
Goecke and Hüther (2016) (11)	2000–2011	Coefficient of variation	1289 European regions	The correlation between a high initial level of GDP per capita and a growth rate in this variable below the EU average is significant
Panzera and Postiglione (2022)(12)	2003-2016	spatial Mankiw–Romer–Weil and Gini index	EU27 NUTS 2	Convergence at NUTS 2 level which have influence in pattern of their growth
Panzera and Postiglione (2014) (13)	1981–2008	Spatial Durbin Model; Bayesian Interpolation Method	103 Italian regions	A variety of growth patterns seem to support the existence of disparities among the Italian provinces
Soukiazis and Antunes (2004) (14)	1991-2000	B-Convergence was calculated using least squares dummy variables and pooling	30 Portuguese regions	Convergence is more conditional than absolute

Research	Analysis Period	Method	Research Sample	Result
		the data for OLS estimation (LSDV)		
Paas, Kuusk, and Schlitte (2004) (15)	1995–2002	β-convergence OLS; spatial lagged model; spatial error model	EU25 countries	During the EU's pre-enlargement phase, the EU15 and the new member states (NMS) witnessed absolute regional income convergence

Table 2: Data

Years	Minimum GDP per capita	Maximum GDP per capita	Average GDP per capita	STD	Regions with GDP per capita higher than average	Percentage of Regions with GDP per capita higher than average
2000	800	84200	18014.8	11045.9	595	50.90
2001	1000	91600	18686.23	11321.81	599	51.24
2002	1100	84600	19187.77	11412.70	594	50.81
2003	1200	83900	19573.05	11515.20	586	50.13
2004	1300	85100	20289.82	11751.31	589	50.38
2005	1500	89900	20884.52	11899.98	580	49.62
2006	2000	90300	21973.05	12348.08	570	48.76
2007	2300	97300	23160.65	12788.93	558	47.73
2008	2600	97400	23716.68	12726.37	553	47.31
2009	2500	91100	22628.4	12296.98	561	47.99
2010	2400	112400	23531.65	13056.35	556	47.56
2011	2700	128300	24396.58	13790.54	556	47.56
2012	2800	127500	24604.11	14030.39	550	47.05
2013	2900	127600	24885.71	14298.95	555	47.48
2014	3000	136200	25500.26	14678.17	551	47.13
2015	3000	131800	26111.29	14857.06	546	46.71
2016	3100	177400	26755.52	15640.82	552	47.22
2017	3500	165300	27724.81	15906.58	544	46.54
2018	3600	180900	28522.93	16286.58	537	45.94
2019	4000	191900	29436.36	16725.50	543	46.45

Table 3: Inequality indexes

Years	COV	Theil	Gini	Moran's I
2000	0.613	0.192	0.326	0.573
2001	0.606	0.185	0.320	0.56
2002	0.595	0.179	0.315	0.562
2003	0.588	0.177	0.312	0.566
2004	0.579	0.171	0.308	0.561
2005	0.579	0.171	0.308	0.546
2006	0.562	0.157	0.297	0.539
2007	0.552	0.149	0.291	0.527
2008	0.537	0.139	0.283	0.519
2009	0.543	0.144	0.286	0.523
2010	0.555	0.148	0.290	0.51
2011	0.565	0.151	0.294	0.506
2012	0.570	0.153	0.297	0.507
2013	0.575	0.154	0.298	0.507

Years	COV	Theil	Gini	Moran's I
2014	0.576	0.154	0.299	0.508
2015	0.569	0.151	0.296	0.516
2016	0.585	0.155	0.298	0.487
2017	0.574	0.150	0.294	0.489
2018	0.571	0.147	0.291	0.477
2019	0.568	0.144	0.288	0.471

7. Figures

Figure 1: Theil Index

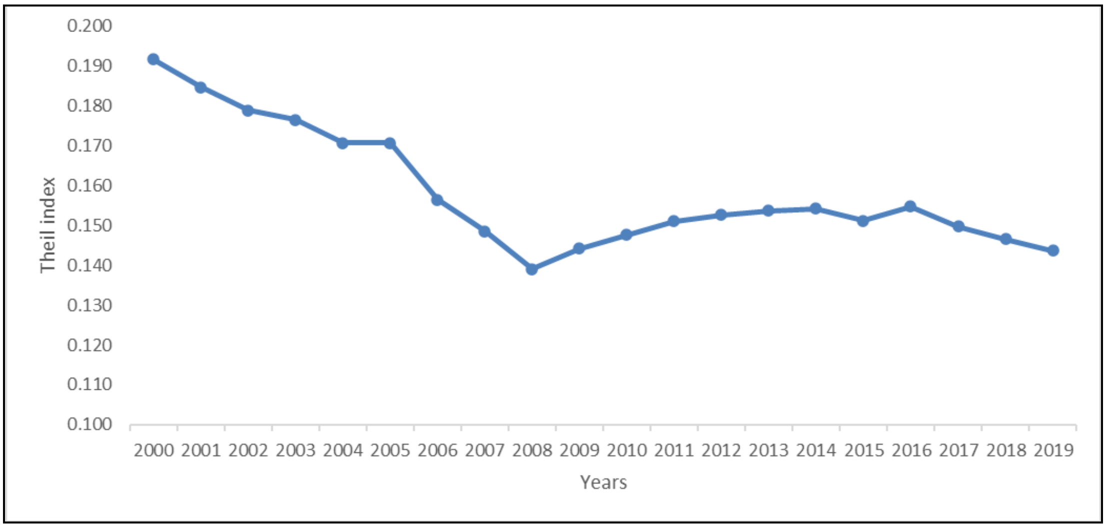

Figure 2: COV index

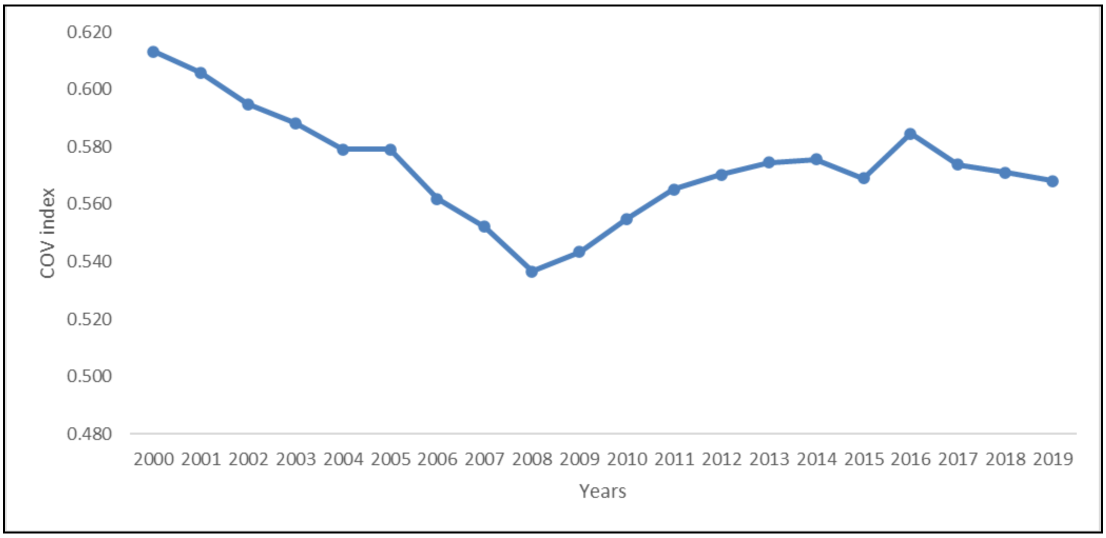

Figure 3: GINI index

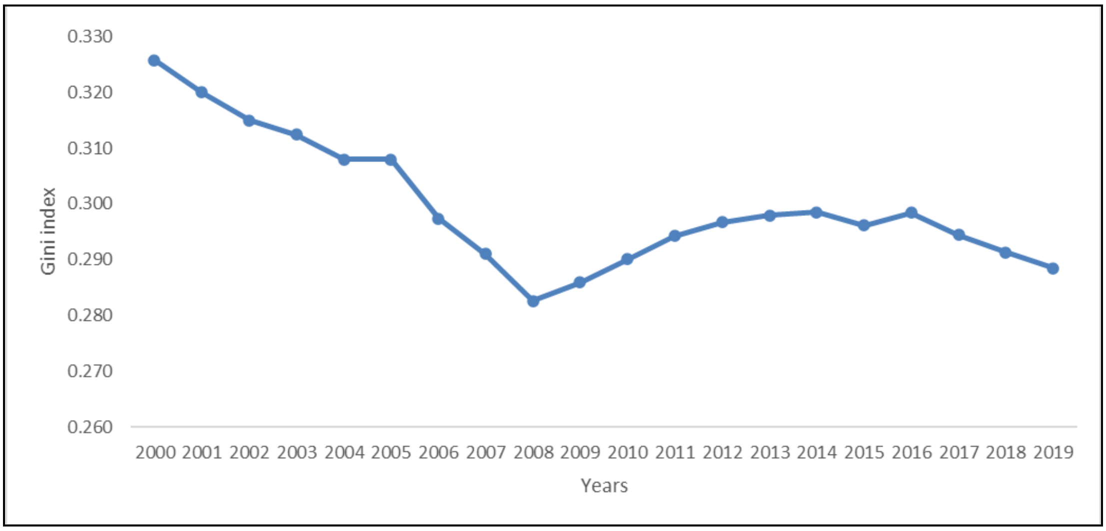

Figure 4: Inequality Indices

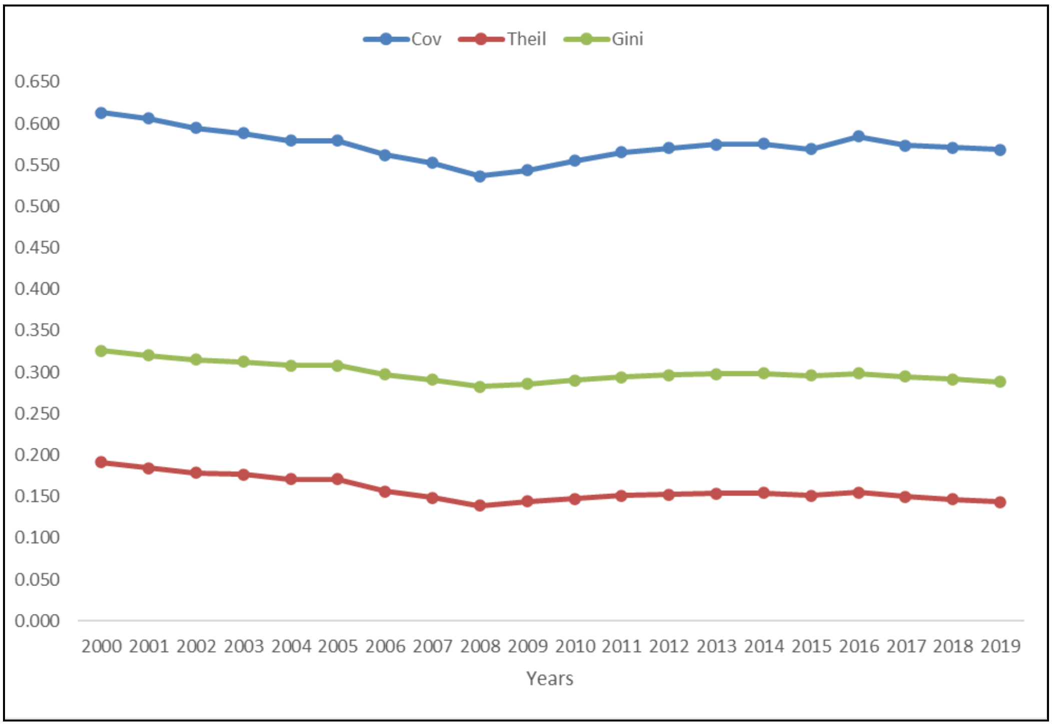

Figure 5: Morans's I index

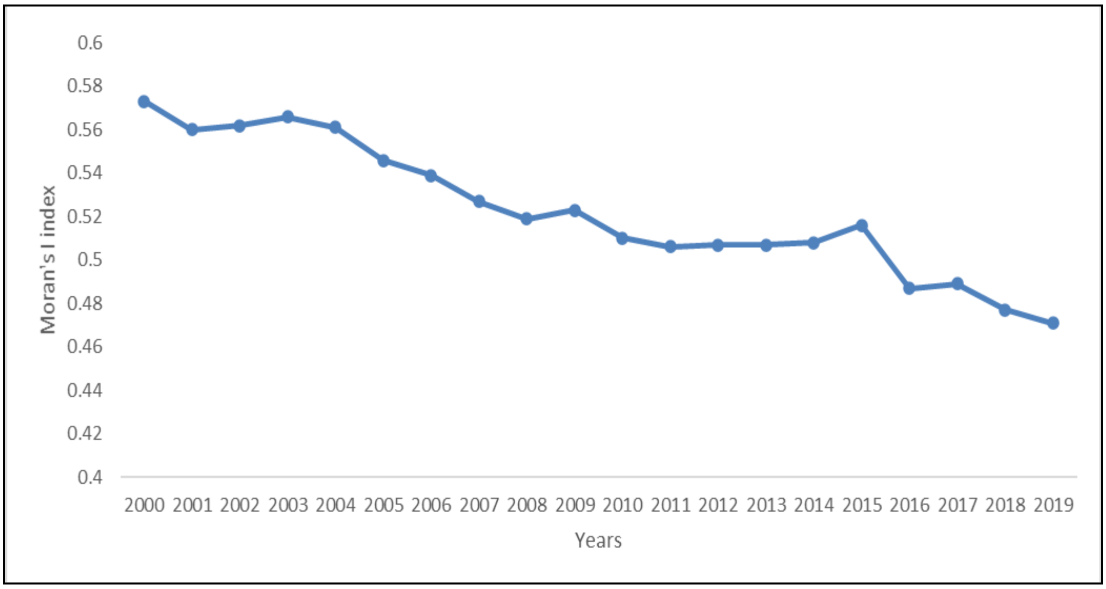

Figure 6: Clustering Map in 2000

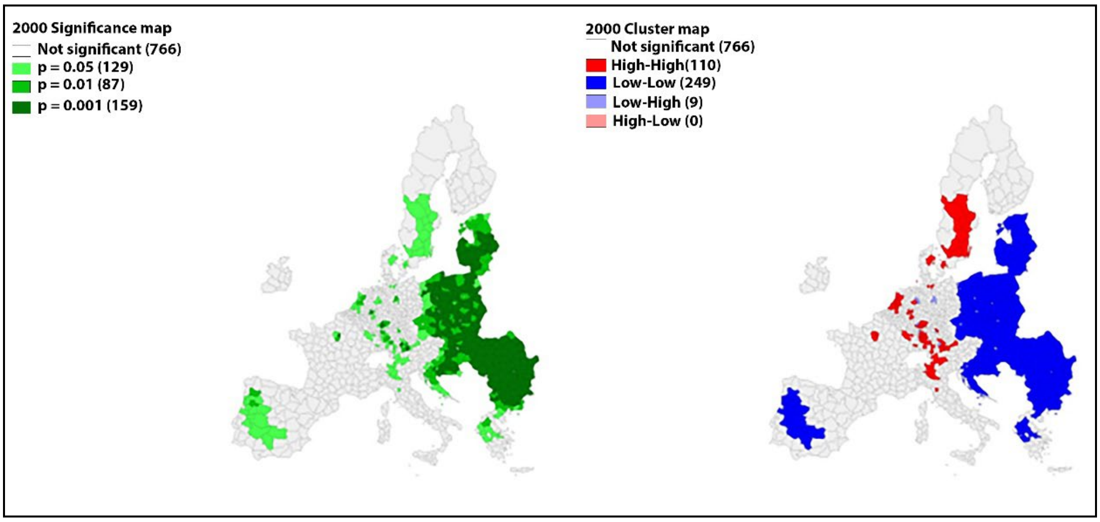

Figure 7: Clustering Map in 2008

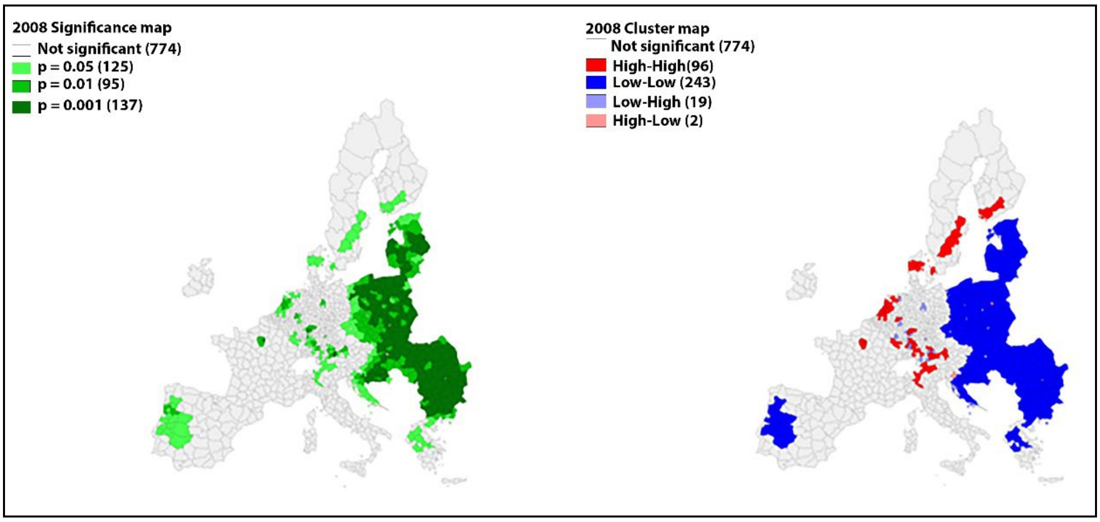

Figure 8:Clustering Map in 2019

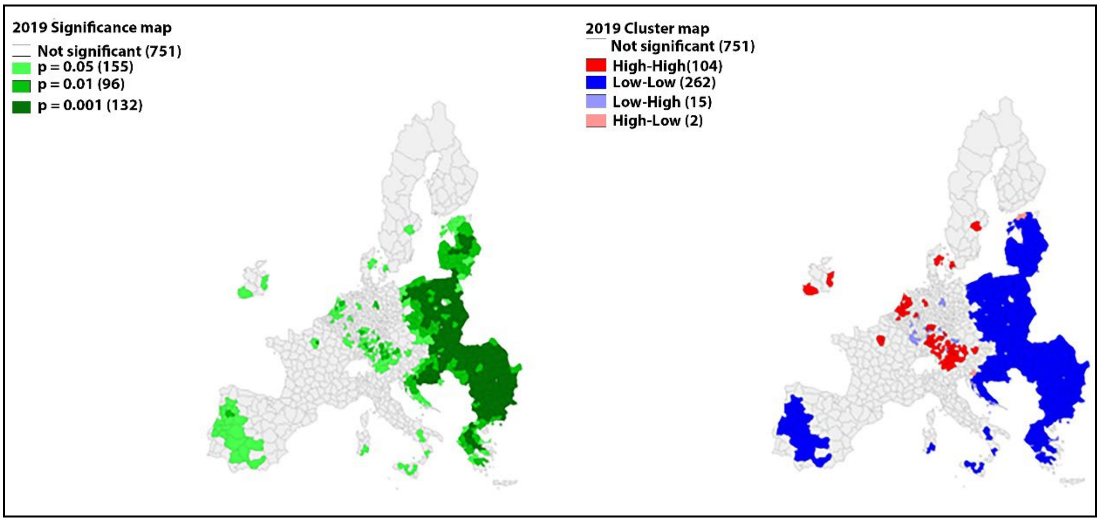

Figure 9: Kernel density graph

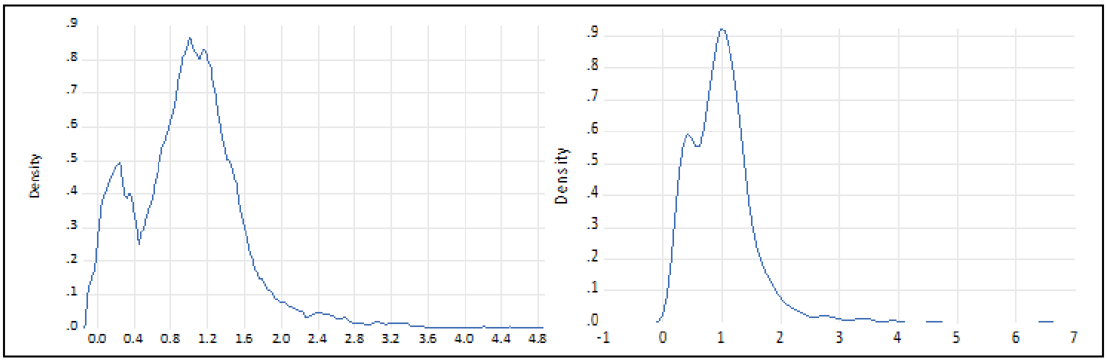

Figure 10: Relative Income in 2000

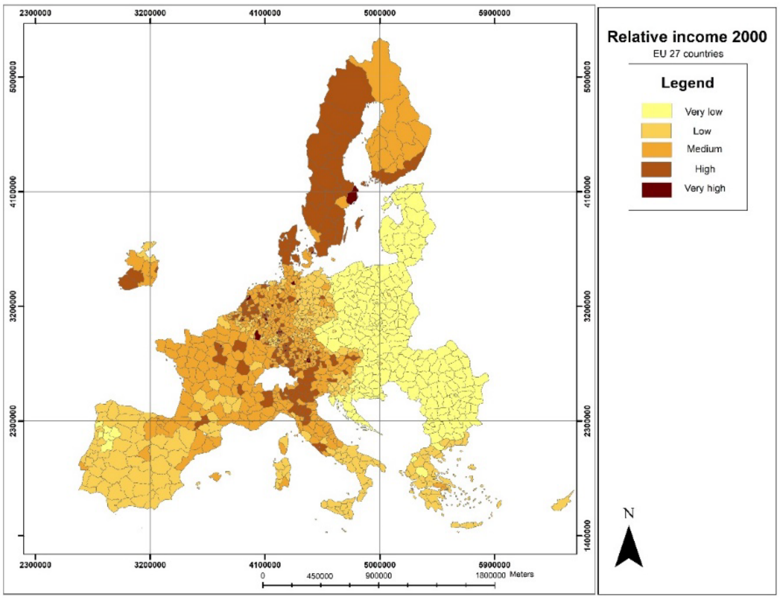

Figure 11: Relative Income in 2019