

Article

Deprivation and Regional Cohesion as Challenges to Sustainability: Evidence from Italy and Greece

Enrico Ivaldi *  and Margaret Antonicelli

Faculty of Communication Department of Humanistic Studies, IULM University, 20143 Milano, Italy; margaret.antonicelli@iulm.it

* Correspondence: enrico.ivaldi@iulm.it

Abstract: Italy and Greece share many structural and economic similarities, including high regional disparities and marked asymmetries between dynamic metropolitan areas and structurally weaker regions. Both countries also face high public debt and an aging population, conditions worsened by recent economic crises. These challenges have significant implications for sustainability, as economic hardship often leads to inefficient resource use, underinvestment in green infrastructure, and socially unsustainable outcomes. Promoting socio-economic and environmental sustainability thus requires addressing territorial inequalities through integrated policies that balance growth, equity, and ecological responsibility. This study introduces a spatiotemporal application of the Peña Distance (DP2) method, allowing for a dynamic and multidimensional analysis of socio-economic deprivation at the NUTS 1 level. The results confirm persistent disadvantages in remote Greek regions and Southern Italy, where youth outmigration and limited development opportunities are prevalent. These regions are affected by multiple, interconnected forms of vulnerability that compromise their prospects for long-term sustainable development, underlining the need for timely and coordinated interventions across different policy levels.

Keywords: deprivation; sustainability; DP2; NUTS 1 regions; socio-economic inequalities; territorial cohesion; European policies



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1. Introduction

In recent decades, socio-economic deprivation has increasingly emerged as a critical obstacle to achieving sustainable development, particularly in Southern European countries where structural vulnerabilities persist. Italy and Greece, both members of the European Union, are characterized by pronounced territorial disparities, aging populations, and economies that are vulnerable to external shocks [1]. These two countries exhibit similar socio-demographic and institutional challenges—such as high public debt, labor market rigidity, and youth emigration—despite their distinct political trajectories and governance systems. Regional imbalances between more developed urban areas and less developed peripheral regions are particularly acute, undermining efforts toward inclusive growth and social cohesion [2].

As noted by Salvati and Zitti [3,4], Italy exemplifies a polarized development model between the economically advanced north and the underdeveloped south, shaped by long-standing territorial and environmental asymmetries.

The European Union has emphasized the need to reduce such disparities through cohesion policy instruments and the Sustainable Development Goals (SDGs), which explicitly address inequality (Goal 10), poverty reduction (Goal 1), and the promotion of sustainable

cities and communities (Goal 11). Nevertheless, the persistence of material deprivation in various parts of Europe highlights the difficulty of aligning macroeconomic recovery with territorial equity [3]. While GDP-based measures offer a partial understanding of territorial development, composite indicators of socio-economic deprivation provide a more nuanced perspective by capturing multiple dimensions of well-being and exclusion [1].

While GDP-based measures offer a partial understanding of territorial development, composite indicators of socio-economic deprivation provide a more nuanced perspective by capturing multiple dimensions of well-being and exclusion (Paolizzi, Ciaffi & Scoppetta, 2021) [5,6].

This paper contributes to this growing field by offering a comparative and dynamic analysis of socio-economic deprivation in Italy and Greece at the NUTS 1 regional level. Using the DP2 method—a robust multidimensional technique for constructing composite indicators—we analyze Eurostat data over the 2019–2023 period to assess spatial and temporal patterns of deprivation [1]. By integrating a longitudinal perspective, this study not only identifies the most disadvantaged regions in both countries but also evaluates how deprivation evolves over time in response to policy changes and broader socio-economic conditions. This study contributes to the broader literature on regional disparities and sustainable development in Southern Europe by integrating the DP2 methodology into a comparative and dynamic territorial analysis. While several indices—such as the EU’s Regional Competitiveness Index (RCI) and the Social Progress Index (SPI)—provide valuable insights into multidimensional regional performance, they often rely on static cross-sectional data or composite scores heavily dependent on normative weighting schemes. In contrast, the DP2 method offers a non-compensatory, data-driven alternative that minimizes informational redundancy and allows for spatiotemporal comparisons, making it particularly suitable for tracking material deprivation over time.

Moreover, the study adds to ongoing debates around convergence and divergence within EU regional policy, especially in the context of “multispeed Europe” and “convergence clubs”. By clustering Italian and Greek regions according to their deprivation trajectories, the research highlights the emergence of persistent structural gaps, revealing that some territories are diverging rather than converging—a finding consistent with the literature on territorial polarization and uneven development paths in the EU.

In line with SDG 10 (Reduced Inequalities) and SDG 11 (Sustainable Cities and Communities), this study emphasizes the relevance of territorial justice and cohesion as prerequisites for sustainability. Recent frameworks for regionalized SDG monitoring in Europe further underscore the need for disaggregated, longitudinal analyses that move beyond national averages [7]. By anchoring the DP2-based approach within these agendas, this study offers a methodological tool aligned with the Agenda 2030’s call for evidence-based, place-based policy action.

The main objective of this research is twofold: first, to provide a robust comparative assessment of regional deprivation in two Southern European countries using a synthetic indicator that respects non-compensatory aggregation principles, and second, to draw attention to the persistence of territorial inequalities as a major barrier to sustainability. Ultimately, the findings aim to inform more targeted and effective regional development policies within the broader context of sustainable and inclusive growth. The novelty of this study lies in three key elements:

- (a) The longitudinal and comparative approach covering the 2019–2023 period in both countries;
- (b) The use of material deprivation indicators from Eurostat, rather than traditional economic measures such as GDP or unemployment, to better capture social vulnerability;

- (c) The clustering of NUTS 1 regions based on DP2 trajectories to distinguish structurally persistent areas from those showing signs of improvement.

To reflect these contributions more clearly, both Sections 1 and 4 have been revised to articulate the research gap addressed and to emphasize the policy relevance of our findings.

1.1. Material Deprivation and Sustainability: Challenges, Disparities, and Inclusive Development

Material deprivation is a multidimensional issue that has an impact on sustainability in social, economic, and environmental dimensions. It has been defined as limited access to vital goods and services, leading to a decline in individual and collective welfare. According to the literature regarding deprivation, in contexts shaped by economic crises, territorial inequalities, and lack of development pathways [1,2], small economic vulnerability may block access to basic goods, wasting sustainability [1]. Rigid labor markets further compound instability for people in precarious employment who are looking for jobs and financial security. Economic disparity is driven by differences in financial access and job opportunities [3]. Social sustainability encompasses the need to alleviate levels of material deprivation and promote inclusion. Investing in early life, for example, through programs like Chile's Mil Días-San Miguel, helps reduce intergenerational poverty and improve the environment we live in [8]. Convergence also takes place in other regions, for instance, the convergence policies in Europe—Europe 2020 strategy focused on the reduction in poverty and equality—have different speeds; yet cohesion processes are challenged through a so-called “multispeed Europe” [3].

Economic crises and global health emergencies like the COVID-19 pandemic have widened internal divides, constraining homogeneous economic and social stability [5] in the EU. A lack of means restricts employability and increases dependency on welfare. Especially in sectors of farming and rural communities, the pandemic has disproportionately affected vulnerable groups. In Europe, slowdowns in the economy have driven an even larger wedge between the rich and poor workers, generating further social disparities [9]. The diversity of economic resilience among EU Member States acts as a barrier towards the reintegration of marginalized groups [3]. Furthermore, material deprivation is compounded by environmental deprivation, where people in poverty often live in substandard housing with lacking infrastructure—leading to inadequate access to clean water and air. These inequalities exacerbate pollution and climate change impacts, amplifying disparities [1]. These challenges can be mitigated by integrated policies addressing environmental and social issues.

This goes hand in hand with the policies of material deprivation and economic convergence. The disparities remain between EU Member States, and the EU action plan aims to address these issues, but without much success, which can be attributed to a lack of social responsibility among member states. Sustainable social and economic development is challenged by isolationism [3]. The emergence of “convergence clubs”—large behavioral groups separated by distinct levels of development—indicates that convergence does not result in homogenization, but rather in divergence at different levels [3]. Addressing these differences requires new commitments to redistributive policies that ensure equal opportunities for the entire population [1]. Material deprivation is not just a matter of poverty, but an obstacle to global sustainability. The empirical basis highlights the importance of integrated social, economic, and environmental policies to promote fair and resilient societies. Investing in social inclusion and reduced inequalities not only improves quality of life and boosts economic and environmental stability, but it also helps to create a more sustainable model of development. Sustainable convergence requires economic policies oriented towards long-term investments in education, healthcare, and infrastructure, as well as their inclusiveness for each community [10]. Italy and Greece have a lot in common

economically, demographically, and welfare-wise—despite their historical, social, or political differences (particularly in comparison with their best friend and enemy, the Turkish Republics)—especially after the financial crisis [11]. Greece’s 2009 crisis led to bailouts from the IMF and ECB [12], while Italy underwent financial restructuring that led to public spending cuts and structural adjustment to stay out of fiscal insolvency, which is when service and interest payments on the government’s debt exceed the state’s income [13]. Krugman [14] points out the vulnerability of both economies due to high debt levels and a reliance on sensitive industries.

As illustrated by the European Commission, in 2023, 23% of Italians and 26% of Greeks were at risk of poverty or social exclusion, well above the EU average of 21%. Youth unemployment exceeded 30% in Southern Italy and certain Greek regions such as Western Macedonia and Thessaly. These structural challenges exacerbate long-term vulnerabilities and reduce regional resilience to economic and social shocks. Compared with countries such as Germany (3.0%) and France (6.6%), both Italy (4.7%) and Greece (13.5%) show significantly higher levels of severe material deprivation and regional inequality, reinforcing the urgency of targeted cohesion strategies in Southern Europe.

Both countries face the demographic pressure of an aging population that puts pressure on pensions and social services [15]. Compared with Italy, Greece is relatively young, yet it faces the same aging-related challenges [16]. Welfare architectures in Italy and Greece ensure access to healthcare and pensions, but in ways that are neither equitable nor sustainable [17]. Yet both countries have suffered through austerity policies that cut funding for social services, including health care. Italy was also bound by structural limitations, facing budget cuts and dealing with service quality decline—which was an even more acute problem in the south of the country [18]. These territorial imbalances persist and could aggravate, with underdeveloped regions such as Italy’s Mezzogiorno and rural Greece suffering from poor provision of public services and limited economic opportunities [19]. Information and Communication Technologies (ICTs) are now part of the daily lives of hundreds of millions of people, and targeted policies encouraging balanced development and equitable access to resources are needed to address these challenges [20]. The concept of “balanced growth” employed in this study does not imply uniform levels of development across all regions—an outcome that would be both unrealistic and theoretically unfounded. Instead, it refers to the progressive reduction in persistent and excessive deprivation that threatens social cohesion and territorial sustainability. This interpretation aligns with recent debates on the equity–efficiency trade-off in regional development, which recognize that while spatial disparities are inherent to growth processes, the enduring marginalization of certain areas poses a structural risk to national stability and long-term development trajectories [21,22]. Within this framework, the notion of balanced growth serves as a benchmark for interpreting regional trends in material deprivation. Regions whose deprivation levels move closer to the national average are considered to be progressing toward balanced growth, while those exhibiting persistent or widening gaps are classified as structurally disadvantaged.

1.2. Material Deprivation in Italy and Greece

Material deprivation is still a problem in both Italy and Greece, which involves large sections of the population, especially those in the south and the islands. Unemployment, precarious work, and social inequalities, although being addressed by some public policies such as the Citizen’s Income in Italy, remain a major issue [23,24]. According to Eurostat and ISTAT data, in 2023, 27% of Italians were at risk of poverty or social exclusion, and nearly one in four people could not reach an acceptable standard of living. Globally surveyed economic conditions resulting from COVID-19 have aggravated the economic hardship,

resulting in a pattern of rising material deprivation and higher rates of material deprivation in areas already experiencing high unemployment, redundancy, and economic stagnation. Southern Italy—Calabria, Sicily, Campania, and Puglia—is characterized by deep poverty and chronic unemployment. Calabria is one of the poorest regions in the country and suffers from geographical isolation, a lack of opportunities, and poverty, especially for its youth. Sicily is not without its challenges; as elsewhere in Italy, regional inequalities are glaring, with coastal areas benefiting from some economic diversification, while rural areas struggle with poverty and inadequate access to services [25]. Campania, whose capital is Naples, has high rates of unemployment and material deprivation, especially in its more remote and rural areas. Inland areas, which are mainly agricultural and tourist, are still suffering from high youth unemployment, particularly in Puglia. Like Sardinia, the island is polarized, with coastal pockets soaking up tourism-driven growth, while its interior fares less well economically. Although one of Italy's tiniest and most underdeveloped regions, Molise suffers from a high unemployment rate and poor access to stores and services, worsening material deprivation. These southern regions have lagged historically, being both underdeveloped and poorly industrialized. Ongoing poverty is maintained by the absence of both infrastructure and jobs [11].

Material deprivation exists in Greece as well—also with some exceptions depending on low economic development, poor infrastructure, high unemployment, etc. Regions such as Epirus and Western Macedonia, which are mostly rural or industrial, suffer from extreme poverty and have access to few public services. An area of agricultural dependency, Thessaly's rural areas have experienced material deprivation and strife as alternative paths of employment were lacking. The Peloponnese region, even its inland parts, also has a lot of developed tourist areas, though it faces significant rural poverty in its destitution. The East Aegean Islands, which comprise Lesbos, Chios, and Samos, are plagued by high material deprivation, especially in less developed parts, despite tourism being a contributing sector, which has been further intensified by the refugee crisis. These families live on the outskirts of Athens, where it is the outskirts of town that see a high rate of unemployment and poverty [12]. Both the Greek government and the European Union have targeted welfare policies and economic aid aimed at these peripheral communities, but implementation has been described as mixed in effectiveness. This mixed effectiveness may be attributed to a combination of institutional and structural challenges that have historically affected the Greek administrative system. These include limited governance continuity, fragmented implementation frameworks, and constrained administrative capacity—particularly at the regional level. In addition, political instability and frequent changes in policy direction have undermined the long-term coherence of development strategies, contributing to uneven outcomes in addressing material deprivation.

The economic crises each country has been through in recent years—Greece from 2008 to 2018 in particular—have exacerbated material deprivation. In Italy, too, rural and less developed zones are hardest hit with economic hardship, and in Greece too, older, rural areas suffer, while better-off places maintain relative prosperity [13]. This reflects the urgent need for infrastructure and social welfare in both countries, particularly in the context of widespread material deprivation.

2. Methodology

2.1. Data Source

The present study is based on the nine material deprivation indicators collected by Eurostat, which are commonly used to monitor economic exclusion across European Union countries [25]. The present study relies on the nine material deprivation indicators compiled by Eurostat, which are widely used to monitor economic exclusion across European Union

member states [25]. These indicators are part of the harmonized Eurostat methodology and represent core dimensions of material well-being. They include access to essential goods and services such as a washing machine, a telephone, a color television, and the ability to afford a protein-rich meal. Rather than reflecting personal preferences or lifestyle choices, these variables capture enforced lack due to financial constraints, thereby ensuring international comparability and alignment with official EU statistics. Together, these nine indicators constitute the basis of the well-established material deprivation index, which identifies individuals who are unable to afford at least four of the nine listed items deemed necessary for a decent standard of living. Specifically, the indicators refer to the ability to pay rent, mortgage, or utility bills; to keep the home adequately warm; to cope with unexpected financial expenses; to consume a protein-rich meal (meat, fish, or a vegetarian equivalent) at least twice a week; to afford a one-week annual holiday away from home; and to own a personal vehicle, a washing machine, a color television, and a telephone [26]. The selection of these indicators ensures both methodological consistency and high relevance to the socio-economic conditions of Southern European countries such as Italy and Greece. In particular, variables like the capacity to cope with unforeseen expenses or to maintain adequate heating are especially pertinent in these countries, where precarious labor markets, energy insecurity, and social marginalization in peripheral areas are persistent challenges. Together, these indicators capture a wide range of material hardships that directly affect individuals' well-being and have significant implications for achieving the goals of sustainable development [27].

The present study is based on data for the five-year period of 2019–2023, thus enabling the development of material deprivation to be traced over time [28]. Material deprivation refers to the enforced inability to afford a set of basic goods and services deemed essential for an acceptable standard of living. Unlike relative income poverty, which focuses on income thresholds, material deprivation directly measures the tangible effects of economic hardship, including limited access to heating, nutrition, durable goods, and essential services [26].

Although the new material and social deprivation rate was introduced in 2021 (broadening the concept to include aspects of social participation), the entire analysis was conducted taking the nine initial parameters into account [25,26]. This methodological approach ensured the continuity of the assessments and facilitated the comparison of results with those from previous years [29]. The data provide a detailed picture of the economic difficulties faced by many European households and enable institutions to develop targeted strategies to combat poverty. The overarching aim of these strategies is to improve social welfare and ensure a decent standard of living and full inclusion in society for all.

From a territorial point of view, the analyses covered the two Mediterranean countries of Italy and Greece, divided into geographical areas. Specifically, Italy was divided into the following regions: North-West, North-East, Center, South, and Islands. Greece was analyzed according to its first-level administrative subdivision, which encompasses 13 areas: Attica, Central Macedonia, East Macedonia and Thrace, West Macedonia, Epirus, Thessaly, Central Greece, Peloponnese, North Aegean, South Aegean, Crete, Ionian Islands, and West Greece [25,27].

2.2. The DP2 Indicator

The motivation to revise the modelling of socio-economic deprivation using an alternative statistical method stems from the fact that, until now, the index has simply been calculated by calculating the percentages of the nine elementary variables that make up the indicator, with identical weights [25,29–34]. This approach, however, does not facilitate the

identification of the most significant and influential elements in the deprivation status of an individual or a household, thereby overshadowing fundamental characteristics [26].

A distinctive feature of the socio-economic development of countries is not only the high degree of differentiation observed, but also the internal differentiation that is evident between different regions of the country. It is evident that the regions surrounding the capital and economic nerve centers are increasingly less disadvantaged than the rest of the country, which, regrettably, exhibits an extremely high level of deprivation. The necessity to categorize countries according to their regional characteristics is therefore pertinent [32,35–37]. To measure socio-economic deprivation objectively, it is necessary to construct an aggregate indicator.

In constructing multidimensional indicators aimed at measuring socio-economic deprivation, it is essential to ensure consistency between the phenomenon under study and the selected dimensions, avoiding informational redundancy and promoting an integrated vision of well-being. As Maggino [38] notes, the complexity of social reality requires the adoption of flexible methodological approaches capable of integrating both objective and subjective dimensions while preserving transparency in theoretical and technical choices. Similarly, Michalos [39] emphasizes that every composite indicator inevitably incorporates value judgments; for this reason, it is crucial to make explicit the criteria used for selecting, weighting, and aggregating variables. This perspective aligns with key methodological contributions, such as Hellwig [40] for the taxonomic method, Hwang and Yoon [41] for the TOPSIS method, and the OECD-JRC Handbook [42], which provides comprehensive guidelines for constructing composite indicators. This approach has been adopted in the present study, where a synthetic index was developed to enable a robust and coherent comparison of deprivation across NUTS 1 regions in Italy and Greece over a multiyear period. This approach has been adopted in the present study, where a synthetic index was developed to enable a robust and coherent comparison of deprivation across NUTS 1 regions in Italy and Greece over a multiyear period. The use of aggregate data at the NUTS 1 level inherently limits the analytical depth of the study. The absence of more disaggregated indicators—particularly at the household or municipal level—restricts the ability to capture intra-regional disparities and localized patterns of material deprivation. As a result, certain conclusions remain necessarily general and should be interpreted in the context of this structural limitation in data availability. This study intentionally focuses on material deprivation to ensure temporal comparability and methodological coherence. However, we recognize that this dimension does not fully capture the complexity of territorial sustainability, which also depends on environmental, institutional, and infrastructural variables. Future research could integrate complementary indicators (e.g., environmental risk exposure, access to public services, governance quality) to provide a more holistic assessment.

The construction of a summary indicator based on the DP2 method to measure deprivation in Italy and Greece necessitates the identification of the main methodological steps (see Figure 1).

For the present purpose, the utilization of Eurostat's material deprivation index will be employed, with its individual variables forming the basis of our investigation.

A distinctive characteristic of these indicators is that their absolute value can be reliably estimated only when considering their base of indicators (criteria). Consequently, the selection of a base and its corresponding set of indicators constitutes a pivotal concern in the construction of a synthetic indicator of deprivation.

It is imperative to acknowledge the distinctive characteristics of the research domain when formulating a conceptual approach to modeling social and economic deprivation. The DP2 modeling method, which has been meticulously adapted for application in Italy

and Greece, was proposed as a specialized solution to address the specific challenges posed by this undertaking.

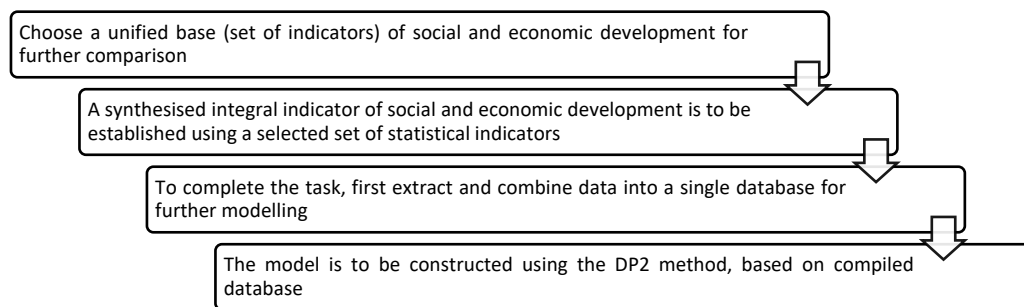


Figure 1. Steps for building an indicator with the DP2 method.

This methodology was originally developed by Professor Pena [43] for the purpose of facilitating inter-spatial and intertemporal comparisons. It was subsequently built upon and augmented by Zarzosa [44], who applied it to research in analogous domains by Somarriba and Pena [45], Nayak and Mishra [46], and Zarzosa [47]. This modeling method facilitates the analysis of extensive datasets. The DP2 indicator, constructed through aggregation and based on econometric P2 distance measurement, enables the comparison of countries across a comprehensive array of variables. This synthetic indicator facilitates the assessment of countries not through a solitary indicator, but rather through an amalgamation of indicators synthesized into a single index. The fundamental premise of the Pena [43] method entails the measurement of the distance between each study area and a hypothetical reference base. The reference base constitutes a theoretical territory that exhibits the most unfavorable results for each individual indicator. Consequently, the DP2 indicator calculates the distance of each studied territory to this imaginary territory, with a value of DP2 equal to 0 for the reference base. The synthetic DP2 indicator is defined as the distance from the country, as determined by the Pena method [43]. This is expressed as follows:

$$DP_2 = \sum_{i=1}^n \left[\left(\frac{d_{ij}}{\sigma_i} \right) \left(1 - R_{i,i-1, \dots, 1}^2 \right) \right] \tag{1}$$

$i = 1, 2, \dots, n; j = 1, 2, \dots, m;$

- j is the country;
- i is the variable;
- n is the number of variables;
- m is the number of countries;
- x_{ij} is the value of the i th variable in the j th country;
- σ_i is the standard deviation of i th variable;
- $d_{ij} = |x_{ij} - x_{ij}^*|$ is the difference between the value taken by the i -th variable in area j and the minimum of the variable in the least desirable theoretical scenario, namely the reference value of matrix X . Therefore, a higher DP2 value signifies a worse outcome, indicating a greater deviation from a theoretical “desirable” scenario.
- $R_{i,i-1, \dots, 1}^2$ is the coefficient of determination in the regression X_i over $X_{i-1}, X_{i-2}, \dots, X_1$, which is already included.

In this study, the linear regression was calculated based on the variables employed in the DP2 model. Utilizing this approach, it is possible to measure the variance of each individual variable [43]. The variance of each individual variable is measured by the determination coefficient.

$$R_{i,i-1, \dots, 1}^2 \tag{2}$$

The factor $(1 - R_{i,i-1,\dots,1}^2)$ is a correlation factor [26] that partially excludes added information that is partially contained in the previous indicators. Thus, duplication of information is avoided due to the correlation mechanism, which includes new information exclusively [43]. It is imperative to delineate the mathematical characteristics of the DP2 indicator. The DP2 synthetic indicator fulfils all the standard properties that the aggregated indicator should possess, as evidenced in the seminal papers of Zarzosa [47,48] and Pena [49].

The primary benefit of this approach over other methodologies is that it addresses critical issues beyond the conventional properties, including the following:

- (a) Arbitrary weighting—by assigning weights based on the inverse standard deviation [47].
- (b) Variable heterogeneity across different measures—by dividing by the standard deviation [36,48,49].
- (c) Information redundancy—through the correlation factor (described above).

This method attracted considerable attention from researchers in 2009 when Somarriba and Pena [48] published the inaugural English-language paper, utilizing the DP2 method to assess the quality of life for European Union citizens. Since then, the DP2 method has been extensively utilized by scientists worldwide for measuring welfare, quality of life, and related concepts such as poverty, at both regional and national levels. The application of the DP2 method for measuring economic and social development is a more recent development.

In this study, the DP2 will be applied to temporal data.

The analysis of the time series and the evaluation of the dynamics of the phenomena based on the statistical characteristics are dominated in this approach [33,50–52]. More specifically, it draws on an analysis of material deprivation based on several indicators and methodologies to track changes in this phenomenon over time so that these developments can be understood in relation to their spatial and temporal contexts [19]. The approach in time allows us to verify not only the absolute levels of deprivation but also the improvement or worsening trends that can be affected by external factors such as social and economic policies or crises (such as recessions or pandemics). This method also involves the application of statistical procedures, including the computation of temporal means and temporal variance, as well as trend analysis, which lend themselves to controlling and predicting changes in deprivation levels and the construction of policies to counter this phenomenon [33,34,50–54].

Finally, one of the greatest strengths of the DP2 method is its ability to reconcile spatial and temporal analyses to succeed in monitoring sustainable development longitudinally. This is performed by merging information from multiple years into a single dataset, where geographic units are comparable both with each other and to the historic path of their performance [51,52]. This characteristic enables policymakers to analyze sustainability plans more effectively in the future.

As a result, the outcomes become comparable across both spatial and temporal dimensions [51,52].

$$DP2_{j,k} = \sum_{i=1}^n \left[\left(\frac{d_{i,j,k}}{\sigma_i} \right) (1 - R_{i,i-1,\dots,1}^2) \right]; i = 1, 2, \dots, n \quad k = 1, 2, \dots, K \quad (3)$$

Because of these attributes, DP2 is a valuable tool for evaluating sustainable development policies, providing a good analytical foundation for developing public policies and action plans for promoting a balance among economic development, social cohesion, and environmental protection.

3. Results and Discussion

To illustrate the premises on which our work is based, we begin with some descriptive statistical considerations. This study is based on the nine elementary indicators underlying the material deprivation index. Table 1 shows the parameters measured on the population, calculated based on having been in that situation or not. The values given are expressed as a percentage (of the total sample).

Table 1. List of variables.

Variables	Identification of the Variables in the Analysis
Paying rent, mortgage, or utility bills regularly	Var 1
Adequately heating the home	Var 2
Handling unexpected expenses	Var 3
Having meat (or equivalent protein) at least every second day	Var 4
Going on at least one week of vacation away from home each year	Var 5
Owning a car	Var 6
Owning a washing machine	Var 7
Owning a color television	Var 8
Owning a telephone (either landline or mobile)	Var 9

We decided to calculate both the Spearman and the Pearson correlations in that analysis to obtain a more complete picture of the relationship of the variables we were studying. The Pearson correlation (Table 2), presuming that the variables are normally distributed and that their relationship can be represented through a linear function, was performed to detect any linear correlations between the individual variables. However, the Pearson correlation is sensitive to outliers and assumes that the relationship between the variables is linear, conditions that are not always met by real data.

Table 2. Pearson Correlation Matrix Overall.

	Var 1	Var 2	Var 3	Var 4	Var 5	Var 6	Var 7	Var 8	Var 9
Var 1	1.00								
Var 2	0.887	1.00							
Var 3	0.963	0.867	1.00						
Var 4	0.837	0.900	0.918	1.00					
Var 5	0.948	0.846	0.926	0.922	1.00				
Var 6	0.880	0.912	0.886	0.900	0.840	1.00			
Var 7	0.854	0.920	0.861	0.892	0.803	0.961	1.00		
Var 8	0.953	0.910	0.937	0.975	0.929	0.910	0.912	1.00	
Var 9	0.932	0.896	0.920	0.959	0.905	0.911	0.913	0.978	1.00

We therefore also calculated the Spearman correlation (Table 3), which indicates the strength and direction of a monotonic relationship, but not necessarily a linear relationship, between the variables. Spearman is also more resistant to outliers, since it is based on ranks rather than raw data. By comparing the two coefficients, we were able to consider whether the relationship between the two variables was indeed linear or if there were any signs of a more complex trend.

Table 3. Spearman Correlation Matrix Overall.

	Var 1	Var 2	Var 3	Var 4	Var 5	Var 6	Var 7	Var 8	Var 9
Var 1	1.00								
Var 2	0.904	1.00							
Var 3	0.919	0.886	1.00						
Var 4	0.898	0.913	0.908	1.00					
Var 5	0.874	0.855	0.815	0.831	1.00				
Var 6	0.878	0.887	0.886	0.876	0.786	1.00			
Var 7	0.921	0.929	0.921	0.925	0.849	0.956	1.00		
Var 8	0.934	0.927	0.942	0.937	0.870	0.912	0.963	1.00	
Var 9	0.910	0.867	0.926	0.916	0.843	0.901	0.949	0.970	1.00

The result of both coefficients turns out to be similar correlation values, implying that the relationship between the variables is monotonic and approximately linear. This explores the homogeneity of data and the credibility of analysis, asserting that either method yielded an acceptable description of the relationship in question. As these data are panel data, the between correlation (Table 4) was also calculated (the correlation over the panel units instead of over time).

Table 4. Between Correlation Matrix.

	Var 1	Var 2	Var 3	Var 4	Var 5	Var 6	Var 7	Var 8	Var 9
Var 1	1.00								
Var 2	0.932	1.00							
Var 3	0.982	0.920	1.00						
Var 4	0.962	0.950	0.942	1.00					
Var 5	0.966	0.921	0.957	0.947	1.00				
Var 6	0.913	0.952	0.921	0.916	0.869	1.00			
Var 7	0.877	0.956	0.889	0.918	0.833	0.979	1.00		
Var 8	0.973	0.957	0.957	0.989	0.945	0.918	0.922	1.00	
Var 9	0.960	0.953	0.945	0.978	0.924	0.934	0.931	0.988	1.00

The “between” correlation matrix detects relationships according to their “between unit” variation (spatial), in other words, according to the differences between the units of analysis (different areas). This means that for each unit, it is possible to obtain an indicator of its general trend because each variable’s average for the observed period is computed first. These averages are then correlated against each other, ignoring internal temporal fluctuations. This is called cross-correlation, and it helps determine whether a unit with a high average in one variable also has a high average in another, or a low average in the same variable.

The analysis of the correlation matrix highlights a strong linear association between all the variables, with values frequently exceeding 0.80. This indicates a close relationship between the factors considered, suggesting the presence of a common latent structure. In particular, particularly high correlations are observed between some variables, such as between Variable 3 (the ability to address unanticipated financial obligations) and Variable 1 (the ability to cover rent, mortgage or utility expenses) (0.963) or between Variable 8 (the presence of a color television) and Variable 9 (the ability to possess a telephone) (0.978), indicating a very strong link between these elements. However, slightly lower correlations are also found, such as that between Variable 5 (the ability to take a one-week vacation away from home at least once per year) and Variable 7 (the ability to own a washing machine) (0.803), which, although remaining high, suggests a less intense relationship than the others.

Then, we wanted to observe how the deprivation phenomenon evolved in the various regions analyzed so that we could make a thorough comparison between not only the states but also between two states in different regions. Material deprivation, both in the Greek regional areas and in the Italian macro-areas, between 2019 and 2023, is reported in Figure 2. Italian regions are represented with dashed lines, while the Greek regions use solid lines.

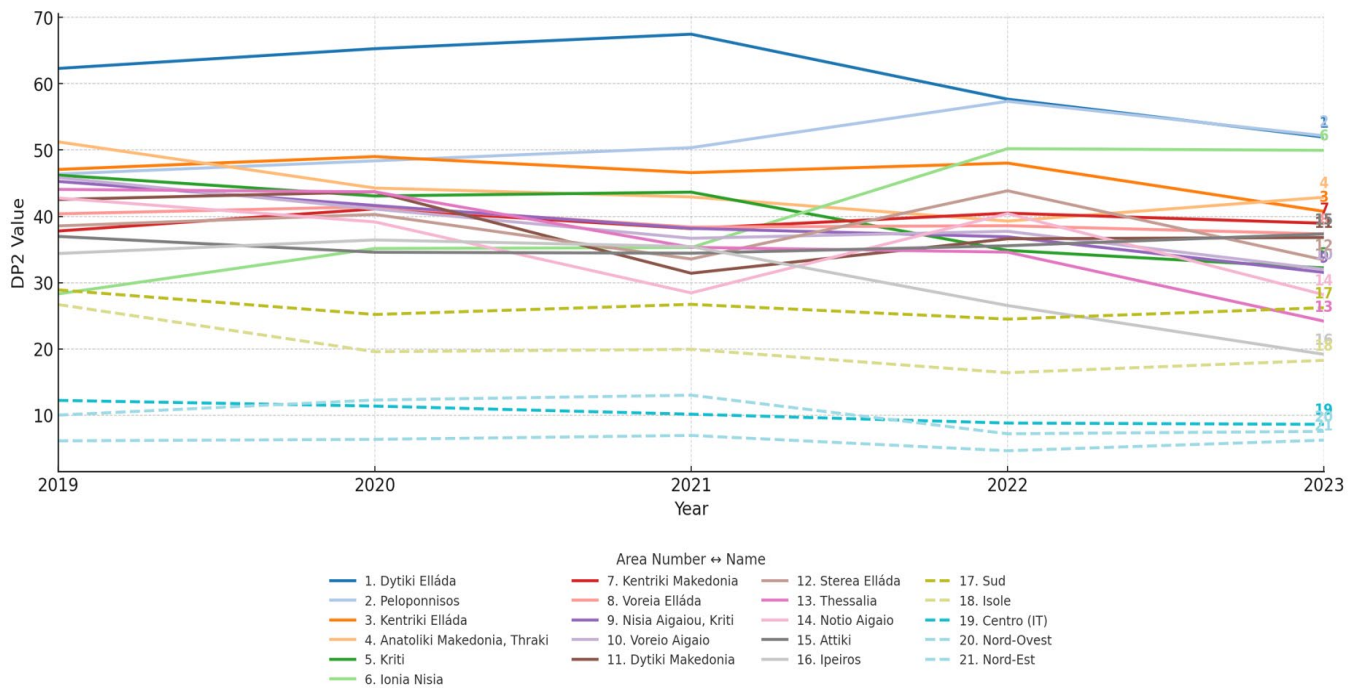


Figure 2. Material deprivation index through DP2 method for Italian and Greek areas, 2019–2023.

The analysis of the curves presents a relevant territorial heterogeneity that, in some cases, has led the regions to record contrasting behaviors over time. Some areas, for instance, Dytiki Elláda and Peloponnisos, exhibit a higher degree of deprivation than others, with a generally upward or unchanged tendency. In contrast, areas such as Anatoliki Makedonia and Thraki appear to have a slight decrease in deprivation across temporal dimensions.

Indeed, the Italian macro-areas that the dotted lines refer to (South, Islands, Center, North-West, North-East) generally experience levels of deprivation lower than most of the Greek regions, indicating a relatively better situation. Further analysis confirms the persistence of territorial gaps within Italy, as Southern Italy and the Islands present higher levels of deprivation than the center-north.

There are areas of deprivation in Southern Italy, or even in some areas of Greece, including Sterea Elláda and Thessalía, that seem particularly interesting because they show high levels and fluctuation of deprivation through time. It may highlight structural criticalities (connected to the socio-economic dynamics and difficulties of some peripheries), which are a pattern commonly observed across regions.

Additionally, although deprivation levels were higher at the beginning of the period for some of the Greek regions, the latter evidently improved over the years, while for others, one can observe an increase in the deprivation level, as is the case with the Dytiki Elláda region. This implies that anti-poverty policies have not been uniformly effective across the territory. The graph indicates the importance of using differentiated and focused actions to combat the specific issue of each locality to minimize socio-economic problems, paying special attention to the historically vulnerable regions.

Data obtained in Table 5 better explain the strong regional variability in Italy, as well as in Greece. Regarding Italy, the data reveal that there are considerable inter-regional differences in levels of material deprivation. The highest rates are still within the southern regions and the Islands while going from higher values in the south, between 24.49% (Abruzzo) and 28.89% (Puglia), and in the Islands, between 16.4% (Valle D'Aosta) and 26.68% (Sardinia), over the years (and especially between 2019 and 2023). They also show a slight decrease for both areas. But the reality is still critical, the south remains permanently in those values, and in 2023, the deprivation rate was 26.21%. In contrast, this analysis reveals that northern regions, like the north-west and the north-east, have much lower levels of deprivation, with values steadily decreasing over time. The north-west, for example, had a deprivation rate of 13.01% in 2021, which fell to 7.54% in 2023, whereas the north-east had the lowest deprivation value, which increased from 6.12% in 2019 to 6.22% in 2023. And there are central regions that, although they have deprivation levels that are lower than the south's, still show rates above the national average, with slight improvements in the period considered.

The data for Greece, on the other hand, indicate a significant heterogeneity in the population's material deprivation levels across the regions.

Table 5. (a) Material Deprivation Index through DP2 method for the Italian area, 2019–2023. (b) Material Deprivation Index through DP2 method for the Greek area, 2019–2023.

(a)		
Region	Year	DP2 Mean
North-East (IT)	2019	6.12
	2020	6.34
	2021	6.93
	2022	4.62
	2023	6.22
North-West (IT)	2019	10.00
	2020	12.28
	2021	13.01
	2022	7.19
	2023	7.54
Center (IT)	2019	12.22
	2020	11.36
	2021	10.13
	2022	8.80
	2023	8.61
South (IT)	2019	28.89
	2020	25.19
	2021	26.71
	2022	24.49
	2023	26.21
Island (IT)	2019	26.68
	2020	19.57
	2021	19.93
	2022	16.40
	2023	18.27

Table 5. Cont.

		(b)	
Region	Year	DP2 Mean	
Attiki	2019	36.96	
	2020	34.58	
	2021	34.43	
	2022	35.56	
	2023	37.35	
Ionia Nisia (GR)	2019	28.30	
	2020	35.14	
	2021	35.29	
	2022	50.21	
	2023	49.96	
Ipeiros (GR)	2019	34.39	
	2020	36.43	
	2021	35.44	
	2022	26.53	
	2023	19.17	
Attiki (GR)	2019	36.96	
	2020	34.58	
	2021	34.43	
	2022	35.56	
	2023	37.35	
Kentriki Makedonia (GR)	2019	47.07	
	2020	49.01	
	2021	46.59	
	2022	48.03	
	2023	40.74	
Sterea Ellàda (GR)	2019	38.55	
	2020	40.28	
	2021	33.56	
	2022	43.85	
	2023	33.42	
Voreia Ellàda (GR)	2019	40.37	
	2020	41.45	
	2021	38.37	
	2022	38.58	
	2023	37.33	
Dytiki makedonia (GR)	2019	37.38	
	2020	41.11	
	2021	38.15	
	2022	40.47	
	2023	38.95	
Notio Aigaio (GR)	2019	45.26	
	2020	41.63	
	2021	38.18	
	2022	36.90	
	2023	31.53	
Thessalia (GR)	2019	44.06	
	2020	43.69	
	2021	35.32	
	2022	34.59	
	2023	24.18	

Table 5. Cont.

Region	(b)	
	Year	DP2 Mean
Nisia Aigaiou, Kriti (GR)	2019	45.26
	2020	41.63
	2021	38.18
	2022	36.90
	2023	31.53
Voreio Aigaio (GR)	2019	45.84
	2020	41.10
	2021	36.68
	2022	37.73
	2023	32.00
Kriti (GR)	2019	46.21
	2020	43.07
	2021	43.64
	2022	34.86
	2023	32.21
Peloponnisos (GR)	2019	46.37
	2020	48.37
	2021	50.36
	2022	57.35
	2023	52.15
Kentriki Ellàda (GR)	2019	37.78
	2020	41.11
	2021	38.15
	2022	40.47
	2023	38.95
Anatoliki Makedonia, Thraki (GR)	2019	51.23
	2020	44.27
	2021	42.92
	2022	39.27
	2023	42.87
Dytiki Ellàda (GR)	2019	62.31
	2020	65.29
	2021	67.48
	2022	57.67
	2023	51.96

High deprivation rates were observed in the islands and the northern parts of the country, including the regions of Nisia Aigaiou, Kriti, and Voreio Aigaio, with values above 45% in 2019 and decreasing through the years, but still with high values in 2023, which were above 30%. The region of Nisia Aigaiou (Aegean islands), for instance, has apparently stable deposits, dropping from 45.26% in 2019 to 31.53% in 2023, but it is one of the most unfavored. Voreio Aigaio also shows a drop: from 45.84% deprivation in 2019 to 32% in 2023. That is why, although Attiki had a relatively high level of deprivation in 2019 (approximately 36%), it continues to be included among the regions with repeated deprivation after that year, reaching 37.35% in 2023. This trend indicates a persistent and resilient form of deprivation in the Attiki region, which includes the metropolitan area of Athens [55,56]. Other regions report variable deprivation rates, such as Anatoliki Makedonia, Thraki, and Dytiki Makedonia; however, as a general rule, the northern and western parts of Greece seem to be more at risk than the establishments that are more developed and have lower deprivation levels have lower deprivation levels, although

the situation in the most isolated and deprived parts of the country remains a major challenge [56].

Similar socio-economic difficulties can be seen in some southern and central parts of Italy, and in parts of southern Greece, but rates of material deprivation differ. The rates of deprivation are relatively high in southern Italy and are stable, or hardly vary, from 2019 to 2023. The situation appears to have at least partially improved, but economic deprivation remains high, particularly in the southern half of the country, where rates are often above 25 per cent, indicating that social and economic vulnerability is still high [55,57].

However, it should be noted again, as we have noted several times throughout this work, that, in Greece, there are regions in the south (and some islands) where such cases of a socially unacceptable level of material deprivation can be seen. Certain isolated and southern areas, e.g., the Aegean Islands and Crete, continue to present rates of 31–45% but show a consistent decline over time [50,56,57]. This has improved somewhat over the years, but there are still complex and influential social structures that have resulted in higher levels of deprivation in some areas than might otherwise be expected in central Italy.

Overall, the two countries appear to suffer from similar problems regarding economic inequity between southern and central Italy and some parts of Greece, but the dispersion of deprivation rates is much wider in Greece, and some areas are better off than others [57].

A deeper examination reveals that the persistent deprivation in Southern Italy is linked to entrenched structural factors such as chronic unemployment, infrastructural deficits, and limited access to quality education and healthcare services. In contrast, certain Greek regions have shown signs of improvement, likely supported by more recent cohesion policy implementations and decentralized welfare programs. These differences underline the need to account for institutional capacity and regional policy responsiveness when designing anti-deprivation strategies.

To graphically illustrate the distribution of the different areas, to record the similarities among them, and to try to analyze how many divisions it was possible to do, a cluster analysis was made through the K-Means methodology. K-Means is a popular clustering algorithm used to partition numerical data into separate clusters. It works best under spherical and equal-variance cluster assumptions [58]. A drawback of K-Means is the need to hand-tune the number of clusters (K), which can be performed through the elbow or silhouette index [58]. It is relatively fast with large datasets but susceptible to outliers that can affect the centroid position [58]. K-Means cannot be used where clusters are irregularly shaped or where the data are categorical; in such cases, other algorithms like DBSCAN or K-Modes would be more appropriate. In addition, it does not support hierarchical structures; thus, a hierarchical clustering approach is more suitable for these scenarios. Hence, the benefits of the methods depend on the type and distribution of data.

Figure 3 presents a 2D cluster analysis of the area and index of material deprivation. It illustrates clusters of areas with similar characteristics and provides an overview of the distribution of deprivation. The different points in the graph represent geographical areas and illustrate that these are grouped by similarity, showing clear clusters, regions that fared worse, and the geographical spread of deprivation.

Table 6 illustrates the division of clusters by geographic area and their respective average index values.

The socio-economic deprivation index averaged over the 5-year span from 2019 to 2023 for each geography is illustrated in Figure 3. This approach was taken to create a more consistent and representative view of socio-economic conditions across the regions, allowing annual variations to be blurred out and deeper, structural differences to be more clearly presented.

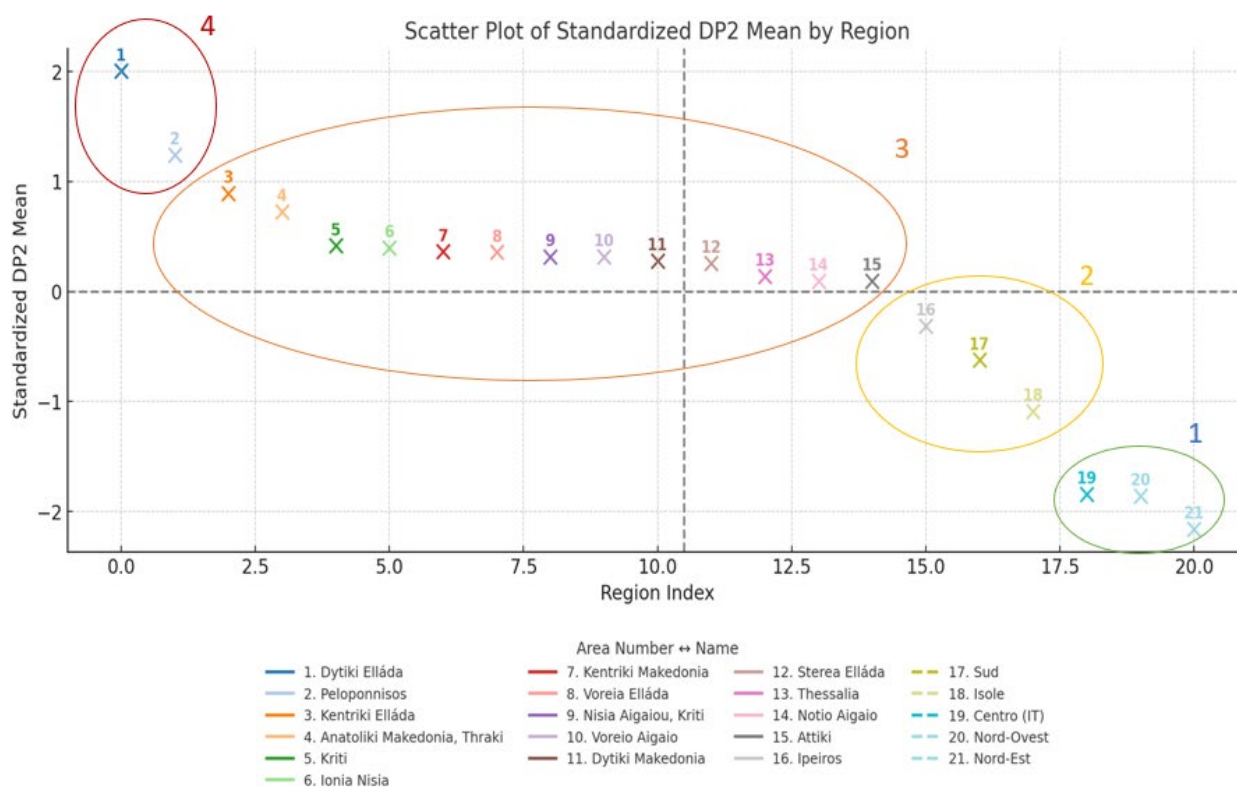


Figure 3. Cluster analysis of average values per DP2 material deprivation index and area.

Table 6. Material Deprivation mean Index belonging to the cluster for the Italian and Greek area.

Region	DP2 Mean	Belonging Cluster
Nord-East (IT)	6.05	1
Nord-West (IT)	10.00	1
Center (IT)	10.22	1
South (IT)	26.30	2
Island (IT)	20.17	2
Ipeiros (GR)	30.39	2
Ionia Nisia (GR)	39.78	3
Attiki (GR)	38.67	3
Kentriki Makedonia (GR)	46.29	3
Sterea Elláda (GR)	37.93	3
Voreia Elláda (GR)	39.22	3
Dytiki makedonia (GR)	39.21	3
Notio Aigaio (GR)	38.70	3
Thessalia (GR)	36.37	3
Nisia Aigaiou, Kriti (GR)	38.70	3
Voreio Aigaio (GR)	38.67	3
Kriti (GR)	40.00	3
Kentriki Elláda (GR)	39.29	3
Anatoliki Makedonia, Thraki (GR)	44.11	3
Peloponnisos (GR)	50.92	4
Dytiki Elláda (GR)	60.94	4

The analysis resulted in the delineation of four separate regional clusters (each representing a different gradient cut-off score and associated level of socio-economic deprivation).

The first one regroups territories that are less deprived (i.e., those of Central, Eastern, and Western Italy). These markets have some of the most stable socio-economic dynamics, including a robust labor market, high median income, and high availability of educa-

tion. Often, these benefits are associated with strong industry or greater levels of urban development.

The second cluster consists of areas of lower deprivation in Southern Italy and the Greek region of Ipeiros. These places are not without some social and economic problems, such as lower employment or income levels, but they are not characterized by the severe disadvantages of the most deprived areas.

The third cluster (most of the sample, nearly all Greek regions) embraces a state of moderate to high deprivation. These regions frequently exhibit mixed profiles—many are during economic change, while others are the focus of policy intervention and cohesion funding. Areas such as Thessaly, Central Greece, and Crete belong to this category.

Finally, the fourth cluster encompasses areas with high levels of poverty, like Western Macedonia and Western Greece. These are territories characterized by high and persistent unemployment, low levels of income, and limited opportunities for education, which do not infrequently reflect chronic structural disadvantages and recurrent economic crises. Figures 4 and 5 present the average results of the material deprivation index for the macro-areas of Italy and Greece, respectively. The clusters are colored from green (cluster 1) to red (cluster 4), progressively indicating more deprived areas.

The results obtained show that the areas characterized by the highest average value of deprivation match the regions that correspond to a part of Southern Italy and Western Macedonia. These areas reflect entrenched socio-economic disadvantages, low incomes, high unemployment rates, and limited access to education and vocational training. It is different for North-west Italy and Attica, which have average values lower than the previous ones, reaffirming their situation as economies with better social and economic conditions.

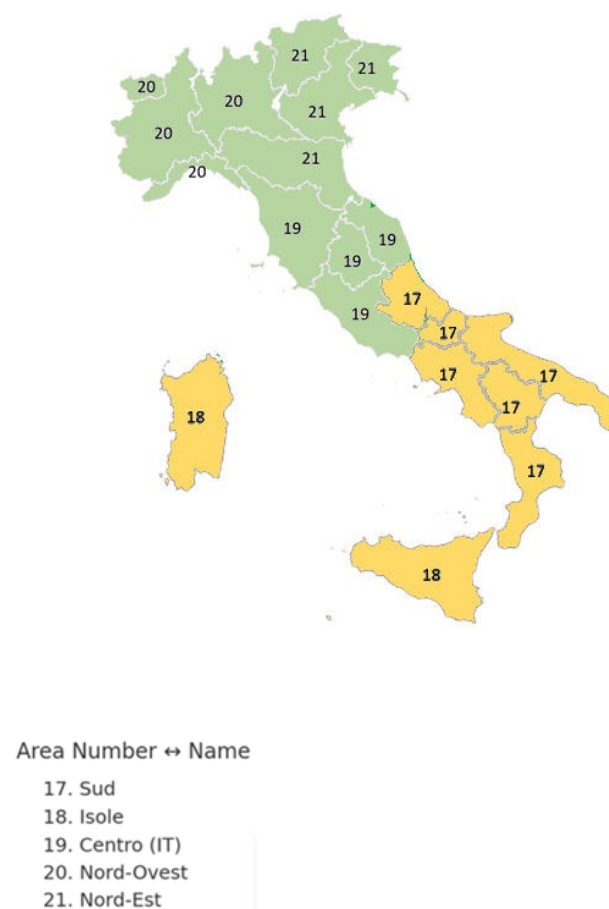


Figure 4. Material deprivation mean index cluster, Italy.

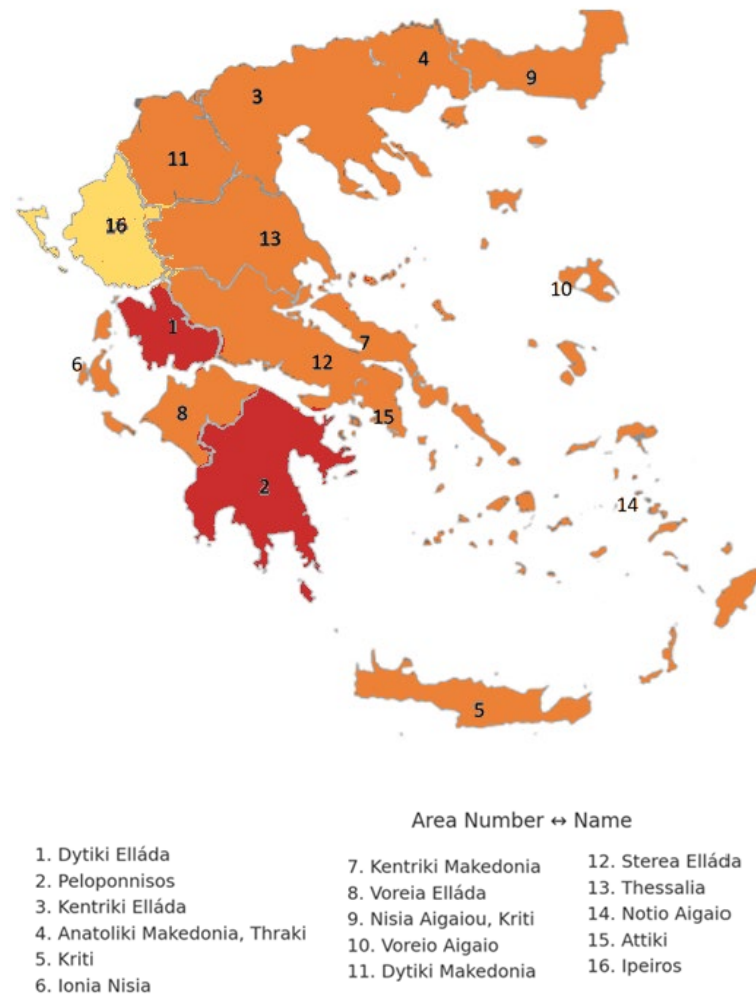


Figure 5. Material deprivation mean index cluster, Greece.

While the overall trends reveal persistent regional disparities, some short-term fluctuations—especially those observed in certain Greek regions during 2020 and 2021—may be partially attributed to the temporary economic effects of the COVID-19 pandemic. These include the impact on tourism-dependent economies, changes in employment stability, and disruptions to household income. However, in contrast, the persistently high levels of deprivation recorded in Southern Italy across the entire period suggest deep-rooted structural disadvantages. These include long-standing labor market segmentation, infrastructural deficits, and limited access to quality education and services. Distinguishing between cyclical shocks and structural deprivation is essential to inform the appropriate design of both emergency responses and long-term regional development strategies.

These regional disparities not only highlight persistent socio-economic fragilities but also raise significant concerns for long-term sustainability. In particular, they reflect structural barriers to achieving the Sustainable Development Goals (SDGs), especially SDG 1 (No Poverty), SDG 10 (Reduced Inequalities), and SDG 11 (Sustainable Cities and Communities). Material deprivation undermines the social dimension of sustainability by limiting access to basic services, constraining individual opportunities, and exacerbating territorial exclusion. Addressing these issues requires place-based strategies tailored to the specific vulnerabilities of each region.

Meanwhile, transition regions (e.g., central Italy and Thessaly) show intermediate mean values, suggesting that these areas possess some aspects of deprivation but retain some aspects of constancy or improvement over time. Using a five-year average minimizes

the impact of any short-term economic shocks and allows us to detect deeper and more reliable structural trends.

The results displayed in Figure 3 indicate that while there are fluctuations year by year in the levels of deprivation, the socio-economic cleavages across regions are relatively stable in the mid-term.

4. Conclusions

This study has highlighted persistent and widening patterns of material deprivation across the NUTS 1 regions in Italy and Greece between 2019 and 2023, using a temporal application of the DP2 method. The results reveal clear territorial disparities—particularly affecting Southern Italy and remote Greek regions such as Peloponnisos and Dytiki Ellàda—where deprivation remains entrenched despite ongoing policy efforts [59–61].

From a policy perspective, the findings suggest that broad, undifferentiated development strategies are insufficient to address structural deprivation. Interventions must instead be regionally tailored and informed by empirical evidence. In particular, regions displaying long-term stagnation or divergence from national trends require targeted support focused on improving administrative capacity, reinforcing intergovernmental coordination, and designing localized development mechanisms [62,63].

Previous policies have often failed due to governance fragmentation, limited implementation capacity at the subnational level, and lack of continuity in planning. For example, in Greece, the mixed effectiveness of policy implementation appears closely linked to institutional instability and insufficient policy integration across governance tiers [64].

To address these challenges, policymakers should consider establishing territorial observatories to monitor regional trajectories of deprivation and evaluate policy outcomes. Additionally, conditional investment frameworks tied to performance indicators could help ensure greater accountability and resource efficiency. Addressing youth outmigration from deprived regions should also become a central policy goal, as it exacerbates demographic imbalances and undermines long-term resilience [65,66].

While this study does not provide cost estimations or simulate policy impact, it offers a robust diagnostic tool to identify priority areas for intervention. Future research based on more granular data—at the household or municipal level—would be essential to validate the observed patterns and refine policy targeting.

In this context, the notion of “balanced growth” used throughout the analysis does not imply uniform development but rather the reduction in persistent deprivation that threatens social cohesion and territorial sustainability. Regions converging toward the national average are considered to be undergoing balanced growth, whereas those diverging or remaining stagnant highlight the need for renewed and region-specific action [67,68].

Despite the valuable insights it offers, this study is subject to several limitations. First, the analysis is based on NUTS 1 level data, as this represents the only harmonized and comparable dataset available from Eurostat. While this ensures methodological consistency across countries, it inevitably reduces the spatial granularity of the results. The findings provide a meaningful overview of regional deprivation trajectories in Italy and Greece; however, further research using more disaggregated data would be necessary to validate these patterns at finer territorial scales and to inform more precisely targeted policy interventions. Although this study effectively captures broad systemic trends, important local-level dynamics may remain undetected due to the inherent limitations of aggregated data.

Second, the exclusive reliance on material deprivation indicators leaves out other socio-economic dimensions—such as environmental sustainability or institutional quality—that could further illuminate regional disparities.

Third, while the DP2 method effectively addresses redundancy among variables, it does not allow for causal inference or account for qualitative heterogeneity across regions, which could enrich the interpretation of observed trajectories. Future research should therefore explore more disaggregated territorial levels (e.g., NUTS 2 or 3), integrate additional multidimensional indicators (e.g., environmental vulnerability, service access), and combine quantitative indices with qualitative insights to capture the socio-political context of persistent deprivation. Such an approach would enhance the explanatory power of territorial analysis and support the formulation of more effective and context-sensitive policy interventions.

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