urban science

Case Report

Cities' Hands Are Tied: Short-Term Economic Impacts of COVID-19 on Natural Population Growth in Metropolitan Greece

Alessandro Muolo [1], Barbara Zagaglia [2], Alvaro Marucci [3], Francisco Escrivà Saneugenio [4], Adele Sateriano [5,*] and Luca Salvati [1,*]

[1] Department of Methods and Models for Economics, Territory and Finance, Faculty of Economics, Sapienza University of Rome, Via del Castro Laurenziano 9, I-00161 Rome, Italy; muolo.1916725@studenti.uniroma1.it
[2] Department of Economics and Social Sciences, Università Politecnica delle Marche, Piazzale Martelli 8, I-60121 Ancona, Italy; b.zagaglia@univpm.it
[3] Department of Agricultural and Forestry Sciences (DAFNE), Tuscia University, I-01100 Viterbo, Italy; marucci@unitus.it
[4] Department of Geography, University of Valencia, Blasco Ibàñez, 28, ES-46010 Valencia, Spain; francisco.escriva@uv.es
[5] Independent Researcher, I-00184 Rome, Italy
* Correspondence: adele.sateriano.pul@gmail.com (A.S.); luca.salvati@uniroma1.it (L.S.)

Abstract: To delineate new directions of urban development in a context of demographic shrinkage in Southern Europe, the present study illustrates a comparative analysis of the demographic balance in metropolitan Athens, Greece (1956–2021). The analysis delineates short-term and long-term dynamics of the natural population balance, considering the impact of the Great Recession and COVID-19 pandemic, and assuming a contemporary increase in gross mortality rates and a marked fertility reduction associated with birth postponement. To address such objectives, we have compared the natural growth of population (the ratio of the total number of births to deaths) at ten year intervals (1956, 1960, 1970, 1980, 1990, 2000, 2009, 2019, 2020, 2021) in 115 municipalities of metropolitan Athens, controlling for the local context. The empirical results of descriptive statistics, spatial analysis, correlation statistics, non-parametric inference, and exploratory multivariate techniques outline the indirect impact of COVID-19 on population dynamics, being in some ways additive to the already observed effects of the Great Recession, reinforcing demographic shrinkage in specific local contexts. The COVID-19 pandemic and the Great Crisis likely accelerated the typical outcomes (population aging and low fertility) of the second demographic transition in Greece. These dynamics are associated with more volatile (and possibly reduced) immigration flows and with enhanced emigration, fueling urban shrinkage and a progressive economic decline of metropolitan regions, as our evidence suggests for Athens. Additional research should ascertain the aggregate, indirect role of pandemics in population dynamics as a proxy of urban and regional decline in European regions exposed to long-term aging.

Keywords: economic cycle; demographic dynamics; natural balance; descriptive statistics; spatial analysis; Southern Europe

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1. Introduction

Demographic, economic, and urban dynamics have always been closely inter-connected [1–4]; economic downturns affect regional population trends differently, depending on the intrinsic divide in urban and rural areas [5]. Especially in conditions of high unemployment in rural districts and growing urban poverty [6–8], the impact of exogenous shocks becomes unpredictable and may encompass both the short and the long run [9]. Malthus was one of the first scholars to relate economic cycles with population changes [10]. Later on, gross domestic product (GDP) growth was correlated with crude population variation rates in both advanced and developing economies [11]. More recently, uncertainties in global socioeconomic scenarios, combined with tough-to-handle health crises, have shaken up how populations change over time [12–15]. This has caused significant issues of informational asymmetry in local labor markets [16] and pushed businesses to cluster more intensively in space [17–19]. As a result, the impact of these population dynamics has been different in regions and countries [20–22].

With this framework in mind, COVID-19 has been demonstrated to accelerate some specific social and demographic dynamics in advanced countries [23–25]. Negative effects of COVID-19 were especially evident in vulnerable local systems [26], influencing demographic trends [27]. This shock seems to have also affected social behaviors, a subject actually under careful scrutiny [28]. Empirical studies have more specifically investigated demographic changes, initially focusing on processes directly involved in the pandemic, such as the differential increase in mortality and the resulting drop in life expectancy [29]. Assumed as processes indirectly connected with COVID-19, fertility decline and more volatile migration flows have attracted increasing attention from scholars following the pandemic [30]. While COVID-19 was initially thought to be a (more or less) temporary phenomenon [31], the assumption of a structural impact on humanity is plausible and requires a detailed investigation into its potential influence on global demographics over longer time windows [32].

In this perspective, although some earlier studies have documented the virus's effect on mortality and, partly, on fertility [33], less attention has been given to the indirect consequences of the COVID-19 pandemic on demographic dynamics and urban development at large [34]. Assuming that the measures taken to contain the disease significantly influenced population dynamics in the medium- and long-term [13], our study focuses on an already compromised demographic setting because of long-term population trends toward aging and lower fertility stemming from individual choices and a healthcare system strained by economic downturns [35–37]. These conditions were frequently observed in the most vulnerable European economies, adding to a noticeable social decline, especially in countries already affected by the 2007 recession, such as Greece, Portugal, Italy, and, partly, Spain [38–40]. The objective of this study is to assess whether the COVID-19 pandemic has accelerated these trends in a metropolitan region exposed to environmental vulnerability, poverty, and social disparities in the Northern Mediterranean basin.

Moving from the regional to the local scale [41], we also investigated whether the COVID-19 pandemic has caused territorial imbalances in demographic dynamics among different districts within the same city, considering together the impacts of mortality increases and fertility declines on natural population balances in Athens' municipalities. The underlying assumption is that distinct contexts demand different policy approaches. Athens has been entrenched in a persistent crisis since 2007, and COVID-19 represents the final blow that is yet to be fully absorbed. It is presumed that this prolonged crisis has further increased the pandemic's effects. In such a demographic scenario, the key idea is that cities and regions necessitate targeted strategies and policies, mindful of the emerging dynamics and territorial disparities, to address the persisting challenges of globalization. Based on these premises, our paper illustrates a comprehensive analysis of the demographic characteristics relevant to Athens' municipalities, discussing in turn how population changes affect socioeconomic development [7]. To achieve this goal, and to help future studies empirically checking our assumption [16], we used standard data sources and a key demographic indicator to analyze the pandemic's impact on population dynamics over time and space [9].

Our work adopted a well-known operational framework [1] analyzing the demographic balance in Greece, one of the European countries most affected by the pandemic, with a comparative focus on regional and local contexts. We ran a detailed comparison of natural population balances over the last 65 years (1956–2021) in the municipalities of the Athens metropolitan region. This timeframe allowed us to consider sequential waves of the Greek demographic cycle, from the baby boom of the 1970s to the subsequent decrease in fertility (1980s–1990s), and from the temporary fertility recovery in the late 2000s to a more evident fertility decrease in the late 2010s accompanied by a continuous increase in mortality rates because of population aging. Official statistics at a spatially detailed level provided us with a comprehensive picture of demographic dynamics in metropolitan Athens, allowing us to capture significant variations over time and better understand how socio-historical events, such as economic expansion (early 2000s), the Olympic Games (2004), the Great Recession (late 2000s), and the pandemic crisis (2020–2021), have influenced the demographic balance at both the local and regional level, possibly influencing the level and spatial direction of urban development.

2. Methodology

2.1. Study Area

We studied the largest part of the administrative region of Attica in Central Greece, coinciding with metropolitan Athens identified in the European Urban Atlas "https://land.copernicus.eu/local/urban-atlas/urban-atlas-2018 (accessed on 2 January 2024)". The area includes seven regional units (Central, Western, Northern, and Southern Athens, Piraeus, and Western and Eastern Attica) and 115 municipalities administering a territory of 3025 km^2 with a resident population of nearly 3.7 million inhabitants. The highest concentration of inhabitants, around 3.1 million, resides in the 56 municipalities within the Athens' conurbation (430 km^2). Athens' population experienced a significant increase between 1951 and 2021; migration historically fueled demographic dynamics until the early 1970s, slowing down in the most recent years during both the economic and pandemic crises.

2.2. Data and Indicators

Short-term demographic dynamics in Athens have been explored using vital statistics such as births and deaths provided by ELSTAT (the Hellenic Statistical Authority, Piraeus). The natural balance was calculated as the ratio of the total number of births to the total number of deaths at ten observation times, namely, 1956, 1960, 1970, 1980, 1990, 1999, 2009, 2019, 2020 and 2021. These years were chosen as representative of (i) a complete metropolitan cycle from urbanization to re-urbanization, (ii) largely differentiated economic dynamics from expansion to recession or stagnation, and (iii) the background shift from the first demographic transition to more recent dynamics associated with the second demographic transition in Greece. By illustrating the local outcome of natural population growth, the index takes values greater than 1 when births exceed deaths (indicating a net (natural) population growth) and values lower when deaths surpass births (indicating a net (natural) population decline).

2.3. Quantitative Analysis

The approach we used resembled putting together different puzzle pieces—looking at various demographic aspects in different ways, e.g., using boxplots and comparing urban and rural areas separately. Understanding the correlation between people's movements and the development of cities can help us to link them to the spatial context [12]. Moreover, this analysis helped us in dealing with complicated data structures, considering both changes over time and across different places, to spot trends in how the population naturally grows in our study area. This approach gave us a detailed view of how different factors connect, showing just how space and population are entangled.

2.3.1. Descriptive Statistics

The statistical distribution of the natural population balance (crude rate of natural population growth, NAT, see above) over time (t) and across the 115 municipalities (s) in the study area was considered the input of (i) seven (descriptive statistic) metrics (i.e., maximum–minimum/mean, 75th–25th/median, median/mean, skewness, standard error, the ratio of urban to rural, the ratio of Athens to Attica), as well as (ii) six metrics derived from information theory and ecological science, as follows:

(i) an aggregate index quantifying evenness in the statistical distribution of the target variable and calculated as $E = e^{H/T}$, where H is the Shannon index and T is the number of time intervals with non-null NAT;

(ii) Brillouin's index (B), another measure of diversity in the rate of the natural population balance, calculated as follows: $B = (\ln(T!) - \sum_i \ln(NAT_i!))/T$;

(iii) Menhinick's richness index (M), providing a gross estimation of heterogeneity in the statistical distribution of NAT as follows: $M = T/\sqrt{N}$;

(iv) the Margalef index (H), ranging from zero to infinity and evaluating the inherent diversification in the rates of natural population growth, as follows: $H = -\sum_i (NAT_i)\ln(NAT_i)$;

(v) the equitability (namely, Pielou's evenness, J) index, computed as the Shannon diversity index (H) divided by the logarithm of T, the number of time intervals with non-null NAT.

(vi) Berger and Parker's index estimating the dominance pattern in a statistical distribution. The index ranges from 0 (all natural balances, hereafter NAT, are equally intense) to 1 (NAT at a given time dominates the time series completely) and was calculated as $S = 1 - \sum_i (NAT_i)^2$.

Maps were used to illustrate the spatial distribution of NAT for representative years (1956, 1970, 1990, 2009, 2019, 2021). Additionally, maps were also prepared with the aim of illustrating absolute changes over time (reflecting the annual rate of population growth or decline) in the natural balance of representative time intervals in metropolitan Athens, as follows: (i) 1990–1999 (the end of the first demographic transition, considered the demographic background); (ii) 1999–2009 (a moderate demographic recovery responding to the volatile economic growth of the 'Olympic decade'); (iii) 2009–2019 (the negative impact of the Great Recession); (iv) 2019–2020 (the short-term impact of the COVID-19 first-wave); (v) 2020–2021 (the short-term impact of the COVID-19 second wave); and (vi) 2019–2021 (the aggregate impact of the COVID-19 pandemic).

2.3.2. Inferential and Correlation Statistics

Correlation statistics were run with the aim of testing the statistical coherence in the local levels of natural population balance over time and space in the 115 municipalities of metropolitan Athens. We tested the statistical coherence of these distributions using both parametric and non-parametric techniques, namely, Pearson moment–product coefficient testing for linear relationships, Spearman co-graduation tests quantifying non-linear pair-wise relationships, and, finally, Kendall concordance tests. All these coefficients were tested for significance (H_0: no pair-wise correlation) at $p < 0.05$ after Bonferroni's correction for multiple comparisons. A pair-wise correlation matrix was provided with the final aim of verifying the spatial coherence of the natural population balance over both short terms (e.g., 1990–1999 vs. 1999–2009) and longer terms (e.g., 1990–1999 vs. 2019–2021). Coherent spatial series of the natural population balance (namely, correlation coefficients close to 1) indicate a substantial stability of the underlying demographic processes over time. In other words, stability and coherence of a given statistical distribution of the natural balance over space may indicate that long-term factors (e.g., the background impact of demographic transitions) prevail in short-term exogenous shocks (e.g., the Great Crisis, COVID-19).

Non-parametric inference was also used to verify significant differences in the statistical distribution (namely, differences in the median value) of the natural population balance at the local scale in 115 municipalities of metropolitan Athens. Using a similar inferential design to the interpretative scheme adopted above with correlation statistics, we tested statistical differences in the natural population balance, comparing 115 observations in the short-term (e.g., 1990–1999 vs. 1999–2009) or in longer time intervals (e.g., 1990–1999 vs. 2019–2021), thus evidencing the possible impact of exogeneous shocks compared with the background trend typical of the second demographic transition in Southern Europe. Significant differences in median values were tested pair-wise (H_0: insignificant differences over median values) using three non-parametric coefficients (Wilcoxon W pair test, Mann–Whitney U test, and Kolmogorov D statistic). All these coefficients were tested for significance at $p < 0.05$ after Bonferroni's correction for multiple comparisons. Significant differences in the statistical distribution of the natural population balance may provide indication of the importance of exogeneous, temporary events, such as recessionary or pandemic shocks, with respect to long-term background trends that exert their effect on natural balances over longer time scales.

2.3.3. Multivariate Analysis

A summary representation of similarity in the spatial distribution of the natural balance in metropolitan Athens was illustrated in a dendrogram derived from a cluster analysis of the six (annual) rates of the natural balance selected and motivated above (at the end of Section 2.3.1: 1990–1999, 1999–2009, 2009–2019, 2019–2020, 2020–2021; the period 2019–2021 was excluded from the analysis to avoid multi-collinearity). Clustering was run using Euclidean distances as the similarity metric and Ward's rule as the amalgamation metric. A comprehensive representation of short-term and long-term trends in the natural population balance in metropolitan Athens was finally derived from an exploratory multivariate data analysis. More specifically, a principal component analysis (PCA) was run on the original data matrix, namely, the two-way table with natural balance rates by year (columns) and municipalities (rows). The analysis (i) identifies important 'latent' factors suitable to describe long-term and short-term demographic transitions occurring in the study area and (ii) correlates those factors with the distribution of the individual variables and territorial contexts. As the analysis was based on the correlation matrix, the number of significant axes (m) was chosen by inspecting the scree-plot and detecting the components with eigenvalues higher than 1. Using a score plot, municipalities were separated into different groups according to their score on the first two PCA axes. Using a loading plot, observation years were ordered in the bi-dimensional space, and time trajectories were traced using a minimum spanning tree approach.

3. Results

3.1. Descriptive Statistics

Figure 1 shows the boxplot concerning the natural balance throughout the whole investigation time window (1956–2021). The analysis enables distinguishing population trends both in the short- and long-term. Until the 1990s, a noticeable spatial heterogeneity among the 115 municipalities in metropolitan Athens was reflected in a particularly high range (max–min) of natural population balances. Moreover, until the 1980s, a relatively stable demographic regime was observed, with median natural population balances ranging between 2 and 3. Population increases, mainly attributable to the consequences of the first demographic transition (high fertility and relatively low mortality rates), reflect an economic phase with a rather young population. However, from the 1990s, a demographic stabilization was recorded with medians reaching 1.5. Until 2009, a new phase of relative stability with moderate growth in the early post-crisis years was observed; territorial disparities decreased, reaching a condition for spatial homogeneity in 1999.

A slight recovery in demographic dynamics was observed in 2009, being the result of economic growth before the Great Recession and rising immigration flows in the early 2000s. The residual growth after the 2004 Olympics was associated with increased birth rates and reduced mortality rates because of the younger migrant population. Ten years later, in 2019, the direct impact of the economic crisis slowed down, and the natural balance fell below 1, on average, indicating negative population growth with lower heterogeneity at the local scale. The indirect impact of the COVID-19 pandemic was reflected not only in the median values, but also in the spatial distribution of natural population balances, with an evident reduction in their maximum values.

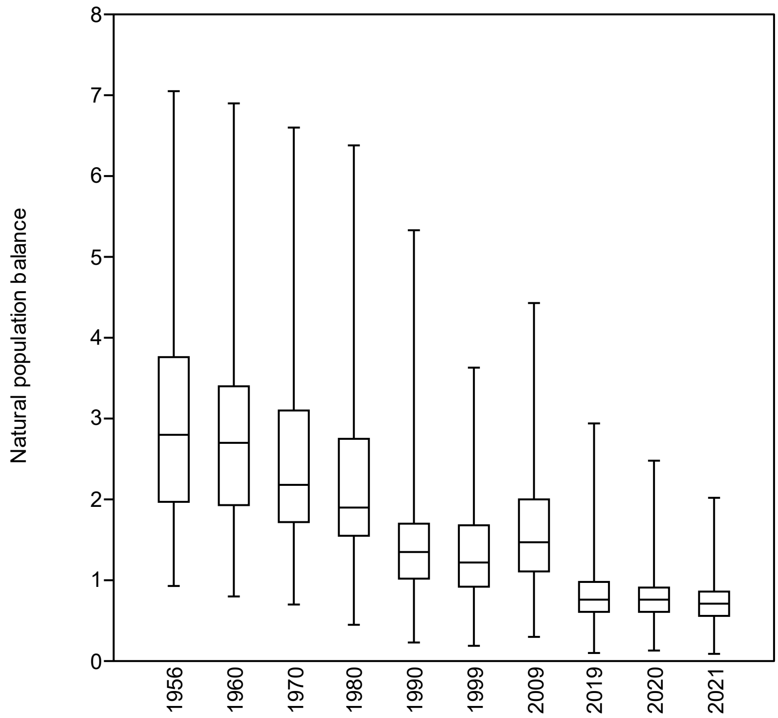


Figure 1. The statistical distribution of the natural balance (i.e., percent rate of natural population growth) over 115 municipalities within metropolitan Athens by year, illustrated using boxplots that represent median, 25th, and 75th percentiles, as well as minimum and maximum values.

The natural balance was compared on a temporal basis considering the average and coefficient of variation and distinguishing the intrinsic dynamics observed in urban and rural locations in metropolitan Athens (Table 1). There is a noticeable downward trend, particularly in urban areas, with the natural balance dropping from 3.26 in 1956 (reflecting increased populations) to 0.69 in 2021, outlining a rapidly decreasing population. In the last three years, especially in urban areas, negative and accelerated demographic dynamics were observed (from 0.76 in 2019 to 0.69 in 2021), being associated with the negative impact on mortality due to the pandemic and the delayed fertility planning in 2020. A similar trend over time was observed in rural locations, albeit with lower levels and variations. The gap between urban and rural areas notably reduced in the 1990s, reversing since 1999, highlighting a greater demographic dynamism in rural areas. In 2009, as mentioned earlier, there was a slight recovery followed by a progressive collapse in the 2010s, likely accelerated by the latent effects of the financial crisis. Demographic rates flattened in both 2020 and 2021, with similar values in urban and rural areas. The statistical variability intrinsic in the natural population balance—consistent with what has been observed in the boxplots—was more evident in the early years of study, with distinctively higher values in urban areas and lower values observed in rural areas. Subsequently, there was a slow decline that made rural areas more heterogeneous compared to urban ones. This process was intrinsically associated with the transformation of rural areas into suburban districts. Economic growth progressively influenced rural areas, moving them from disadvantaged conditions to increased economic interaction with neighboring growth poles. It is worth noting that spatial heterogeneity reduced between 2020 and 2021, especially in urban areas, which became more homogeneous, with the lowest coefficient of variation (0.22) in both years.

Table 2 completes the descriptive analysis of the natural population balance in metropolitan Athens. The statistical distribution of the target variable observed in various investigation years showed a clear asymmetry reflected in the ratio between the median and the mean values, which systematically deviates from 1 (the empirical condition for symmetry). With this perspective in mind, the intermediate observation years have been highly asymmetric in terms of the local population balance, peaking in 1980. Normalized heterogeneity, calculated as the ratio between the difference between the maximum and minimum and the median value, highlights a peak of statistical heterogeneity in the target variable (1990) and a secondary peak in 2019. The effect of COVID-19 seems to have impacted it negatively, although even after normalization, a higher heterogeneity was observed compared to the early observation years. Despite the slight reduction due to COVID-19, an increasing heterogeneity was finally observed in recent years compared with the beginning of the study period.

Table 1. Spatial distribution (average and coefficient of variation) of the natural balance (i.e., percent rate of natural population growth) over the 115 municipalities of metropolitan Athens by year and urban/rural status.

Partition	1956	1960	1970	1980	1990	1999	2009	2019	2020	2021
Average										
Urban	3.26	3.01	2.65	2.44	1.44	1.13	1.35	0.76	0.75	0.68
Rural	2.37	2.35	1.96	1.63	1.31	1.30	1.67	0.78	0.80	0.75
Athens region	2.80	2.70	2.18	1.90	1.35	1.22	1.47	0.76	0.76	0.71
Coefficient of variation										
Urban	0.42	0.40	0.41	0.41	0.49	0.41	0.38	0.41	0.22	0.22
Rural	0.34	0.34	0.38	0.40	0.47	0.47	0.47	0.53	0.56	0.51
Athens region	0.44	0.42	0.44	0.46	0.49	0.44	0.45	0.47	0.45	0.41

Table 2. Descriptive statistics of the natural balance (i.e., percent rate of natural population growth) over 115 municipalities of metropolitan Athens by year.

Variable	1956	1960	1970	1980	1990	1999	2009	2019	2020	2021
Statistical metrics										
Max–min/med	2.0	2.1	2.4	2.7	3.4	2.6	2.6	3.4	3.0	2.6
75–25th/median	3.1	2.7	2.3	1.9	0.9	0.9	1.2	0.2	0.1	0.1
Median/mean	0.94	0.95	0.88	0.85	0.90	0.93	0.92	0.91	0.97	0.97
Skewness	0.90	1.02	1.13	1.33	2.13	1.04	1.35	2.02	1.94	1.35
Std. error	0.122	0.112	0.100	0.096	0.069	0.054	0.067	0.037	0.033	0.028
Urban/rural	1.38	1.28	1.35	1.50	1.10	0.87	0.81	0.97	0.94	0.90
Athens/Attica	0.53	0.62	0.84	0.97	0.70	0.64	0.60	0.84	0.85	0.78
Diversity indexes										
Evenness, $e^{H/T}$	0.914	0.920	0.916	0.907	0.903	0.909	0.912	0.906	0.913	0.922
Brillouin	4.2	4.2	4.1	4.1	3.9	3.9	3.9	3.6	3.6	3.5
Menhinick	6.2	6.4	6.8	7.2	8.8	9.4	8.5	11.8	12.2	12.5
Margalef	19.5	19.7	20.2	20.6	22.1	22.7	21.9	25.0	25.4	25.7
Equitability, J	0.981	0.982	0.982	0.980	0.979	0.980	0.981	0.979	0.981	0.983
Berger–Parker	0.021	0.021	0.023	0.025	0.031	0.024	0.024	0.031	0.028	0.024

The standardized ratio between the 75th and 25th percentile divided by the median value shows a significant reduction in statistical heterogeneity between 2020 and 2021, although a persistent volatility of extreme values was also observed. Although similar, these two indicators reflect slightly different development paths: the former indicator focuses on extremes (maximum and minimum), while the latter takes account of the first and fourth quartiles. There was a reduction in spatial heterogeneity at both the 25th and 75th percentiles, but strong heterogeneity persists, even with COVID-19. Moreover, there was an increase in kurtosis over time, with notable peaks in both 1990 and 2019. COVID-19 seems to homogenize this measure. The standard error of the mean, while showing a decrease over time, remains high, although taking much lower values in the years of COVID-19, with a greater homogeneity.

The ratio between the population balance, respectively, observed at urban and rural locations—as already shown in Table 1—inverted between 1990 and 1999, reaching values systematically below 1. Furthermore, the natural balance ratio between downtown Athens and Attica (basically encompassing the metropolitan area of Athens) increased moderately. This suggests an initially slower demographic dynamic in Athens compared with Attica, aligning in the 1980s but subsequently diverging again, and converging more flatly in 2020 and 2021 likely because of COVID-19. Downtown Athens, initially showing progressively slower dynamics, experienced a relative acceleration due to the pandemic.

The second group of indicators (diversity metrics) focuses on the implicit diversification in the statistical distribution of the natural balance across Athens' municipalities. Diversification increased with COVID-19, indicating a greater spatial homogeneity. The Brillouin metric tended to decrease when homogenization rates increased. Slight increases were reflected in the latent trend of both the Menhinick and Margalef indexes. The Berger–Parker metric remained mostly stable. Thus, a reduction in spatial heterogeneity was observed in values around the mean population balance. While a reduction in both maximum and minimum values was evident, this decline was not as pronounced in intermediate values, thereby maintaining significant heterogeneity in the overall statistical distribution, as demonstrated by several diversity indices.

3.2. Spatial Analysis

Maps illustrating the spatial distribution of the natural population balance in metropolitan Athens (Figure 2) indicate a substantial decline in demographic dynamics all over the study area between 1956 and 2021. At the beginning of the study period, this resulted in a substantially positive population growth rate all over the study area. In the most recent year, positive rates were observed only in a few suburban municipalities. During the last decades, the only recovery was observed in 2009. This is rather evident when comparing maps for 1990 (representative of the initial wave of the second demographic transition in Greece, with progressive aging and fertility decline) and 2009, since relatively few municipalities' (basically urban locations) totalized negative growth rates were reflected in natural balances less than 1.

Figure 3 illustrates local increases (black) or decreases (white) in the natural population balance of metropolitan Athens, comparing specific time intervals on a municipal base. Between 1990 and 1999 (the background conditions typical of the initial wave of the second demographic transition), several municipalities had a decreased natural balance, with only the exception of peri-urban municipalities. During economic expansion (1999–2009), the vast majority of municipalities in metropolitan Athens experienced increasing natural balances. With the crisis (2009–2019), almost all municipalities experienced a huge decline in the natural population balance. The picture was more mixed with COVID-19, since some sparse (urban and rural) municipalities displayed increasing rates and other municipalities (especially suburban) experienced declining rates between 2019 and 2020. Between 2020 and 2021, suburban municipalities east of Athens (usually the most affluent in the area) showed increasing rates as opposed to western municipalities experiencing a generalized decline in natural population balances.

3.3. Inferential Analysis

Results of a correlation analysis (Table 3) provided similar results when adopting parametric or non-parametric coefficients that verify linear or non-linear relationships. All correlations were insignificant ($p < 0.05$, Bonferroni corrected for multiple comparisons), indicating substantially different natural balances over space (municipal level). The only significant coefficients were found for two pair-wise comparisons (1999–2009 vs. 2009–2019 and 2019–2020 vs. 2020–2021). These correlations were significantly negative for Pearson, Spearman, and Kendall coefficients, meaning that the Great Recession (2009–2019) was a turning point in the spatial distribution of natural population balances in metropolitan Athens compared with the previous wave of economic growth, the so called 'Olympic decade' (1999–2009). This result is intuitive and reflects the indirect impact of economic downturns on demographic dynamics. Interestingly enough, a relatively high and negative correlation was also found in the natural population balance between the first (2019–2020) and the second

(2020–2021) COVID-19 waves, suggesting how the demographic outcomes of the pandemic have been relatively heterogeneous and spatially mixed in metropolitan Athens.

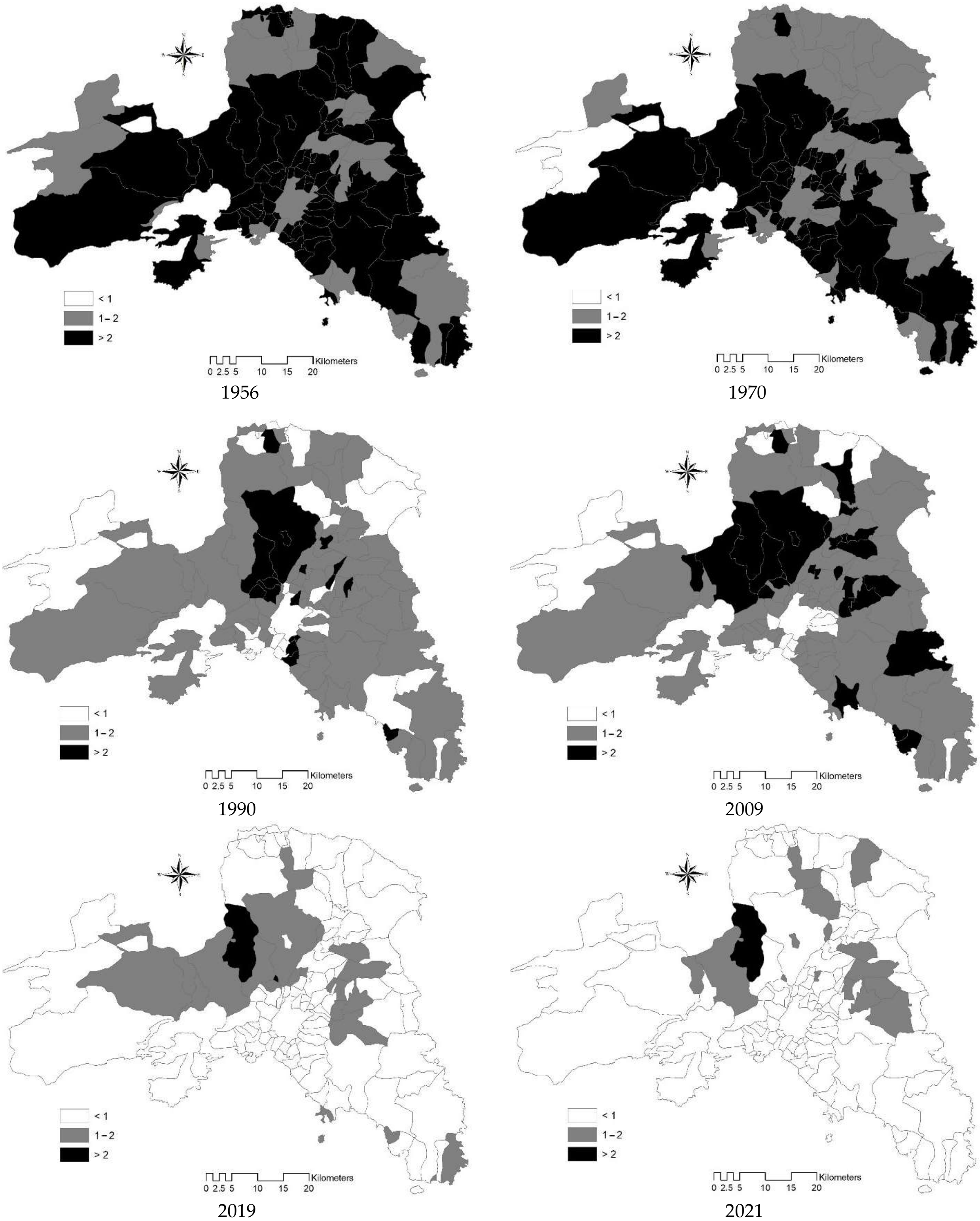


Figure 2. The statistical distribution of the natural balance (i.e., percent rate of natural population growth) over 115 municipalities within metropolitan Athens in representative years reflective of different demographic waves in the study area (see text for details and clarifications; black, grey and white tones, respectively, indicate accelerated population growth, moderate growth, and decline).

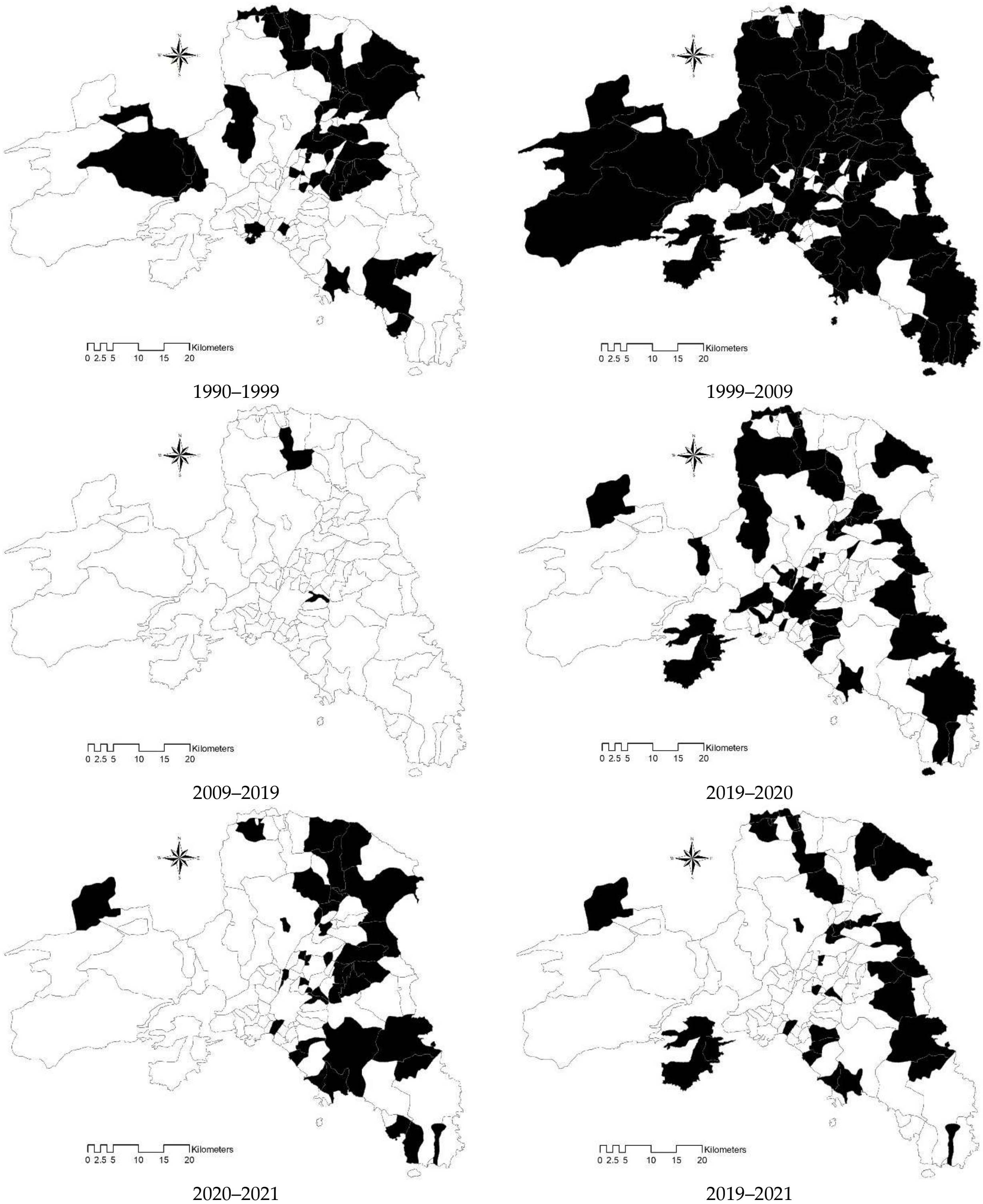


Figure 3. Absolute change over time (annual rate of growth/decline) in the natural balance in metropolitan Athens by representative time periods reflective of different demographic waves in the study area (see text for details and clarifications; black and white tones, respectively, indicate increasing and decreasing rates over time).

Table 3. Correlation statistics of the natural balance (i.e., percent rate of natural population growth) over 115 municipalities of metropolitan Athens by year (bold indicates significance at $p < 0.05$ after Bonferroni's correction for multiple comparisons).

	1999–1990	**2009–1999**	**2019–2009**	**2020–2019**
Pearson				
2009–1999	0.08			
2019–2009	−0.11	**−0.64**		
2020–2019	0.19	−0.01	0.03	
2021–2020	0.04	0.06	−0.17	**−0.35**
2021–2019	0.22	0.03	−0.10	
Spearman				
2009–1999	−0.04			
2019–2009	−0.07	**−0.45**		
2020–2019	−0.01	−0.09	0.07	
2021–2020	0.09	−0.02	−0.03	**−0.42**
2021–2019	0.07	−0.12	0.06	
Kendall				
2009–1999	−0.03			
2019–2009	−0.05	**−0.34**		
2020–2019	0.00	−0.06	0.05	
2021–2020	0.06	−0.01	−0.02	**−0.30**
2021–2019	0.05	−0.08	0.04	

The median values of natural balances were also compared on a time basis using non-parametric inference (Table 4). Different median levels of natural population balance were observed systematically between 1990–1999 and 1999–2009 and between 1999–2009 and 2009–2019. These results document the differential impact of economic downturns (growth and recession) on the long-term demographic background, as represented by the 1990–1999 baseline. The first wave of COVID-19 (2019–2020) showed significantly smaller median natural balances than 2009–2019. This result suggests an incremental impact of early pandemic waves that added to the already negative impact of the crisis. However, these results were not so clear when comparing 2009–2019 with 2020–2021, possibly reflecting the slow recovery observed later on. These results indicate that the negative impact of the Great Recession on demographic dynamics in metropolitan Athens consolidated with COVID-19, although the overall impact of the COVID-19 pandemic was relatively more intense than the impact of the Great Recession.

Table 4. Pair-wise comparisons based on inferential statistics between the natural balance (i.e., percent rate of natural population growth) observed at two different time windows over 115 municipalities of the Athens metropolitan region by year (0.001 < * $p < 0.05$; ** $p < 0.001$, after Bonferroni's correction for multiple comparisons).

		1999–2009	**2009–2019**	**2019–2020**	**2020–2021**	**2019–2021**
1990–1999	Wilcoxon (z)	6.96 **	6.99 **	0.99	1.98 *	4.17 *
	Mann–Whitney (z)	−7.43 **	−8.00 **	−1.34	−2.46 *	−4.58 *
	Kolmogorov (D)	0.47 **	0.48 **	0.28	0.36 *	0.47 *
1999–2009	Wilcoxon (z)		9.13 *	3.64 **	4.64 **	5.88 **
	Mann–Whitney (z)		−12.3 *	4.66 **	−5.41 **	−7.05 **
	Kolmogorov (D)		0.83 *	0.48 **	0.51 **	0.60 **
2009–2019	Wilcoxon (z)			1.93 *	0.86	1.51
	Mann–Whitney (z)			−2.54 *	−1.28	−1.35
	Kolmogorov (D)			0.39 *	0.34 *	0.28
2019–2020	Wilcoxon (z)				0.53	
	Mann–Whitney (z)				−0.58	
	Kolmogorov (D)				0.08	

3.4. Multivariate Analysis

Results of a hierarchical clustering (Figure 4) run on the annual rate of change in the natural population balance (municipal scale) in metropolitan Athens indicate a substantial similarity over time. Dissimilar periods were those more distant on a temporal basis, confirming the role of demographic stationarity and ergodicity over time. Interestingly, the COVID-19 pandemic was associated with demographic dynamics (natural balances) particularly different from those observed in the earlier time interval. In particular, natural balances recorded between 2019 and 2020 diverged substantially from those observed during the Great Recession and the 'Olympic decade', indirectly stating the peculiarity of COVID-19 as far as population growth and decline are concerned.

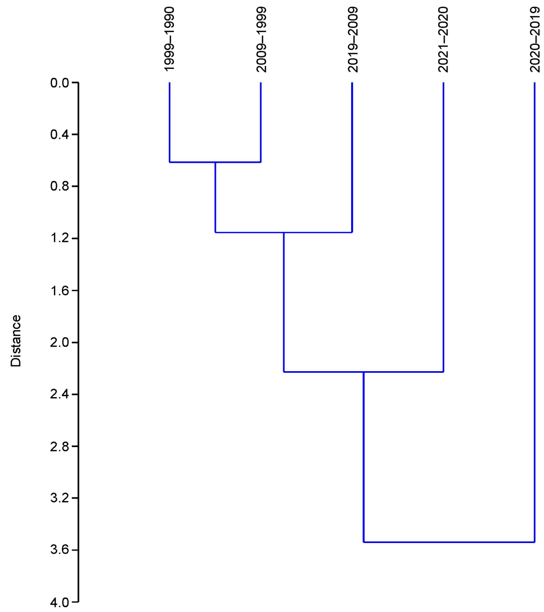
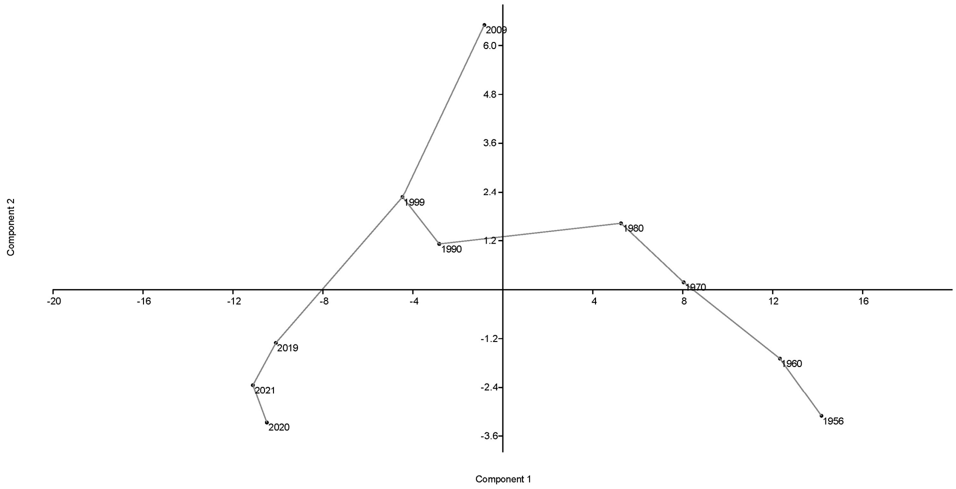
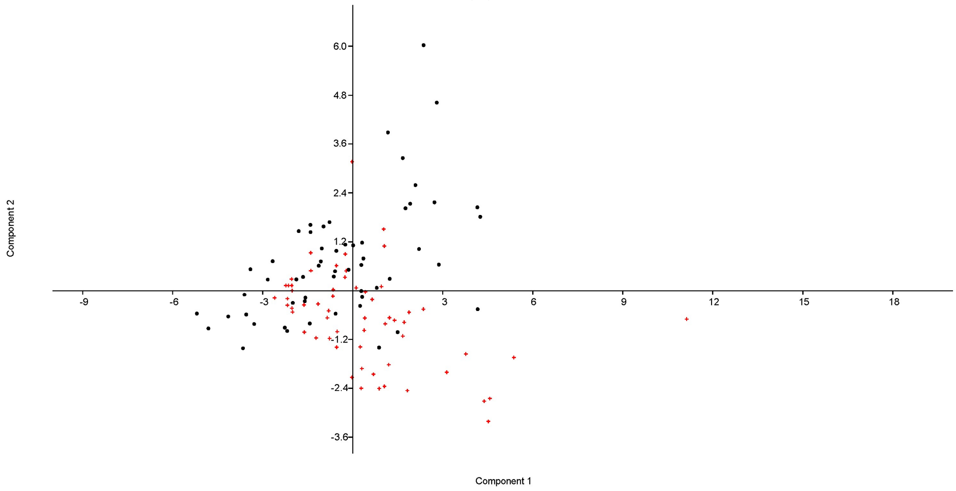


Figure 4. Similarity in the annual rate of change in the natural population balance in metropolitan Athens by time interval reflective of different demographic waves in the study area (see text for details and clarifications; Ward's amalgamation rule).

Results of a principal component analysis (PCA) aimed at reducing data matrix dimensionality are provided in Figure 5. Observation years are placed along the columns, while the 115 municipalities in Attica are illustrated along the rows, highlighting two distinct colors in the right graph (black for urban areas and red for rural ones). PCA produced two graphs: a loading plot (a) ordering the years through a minimum spanning tree from right to left. The time course of observation years was basically associated with Component 1 (which explains 78% of the variance) and covers the time horizon from 1956 to 1999. Component 2, accounting for less than 10% of the total variance, shows a vertical trend from 1999 to 2021. This indicates two spatial dynamics: (i) a sort of demographic acceleration followed by a gradual reduction over the first time set (1956–1999) and (ii) a subsequent spatial diversification between 1999 and 2021 in a context of declining dynamics after a period of relative stability. It is evident how urban and rural areas react and distribute themselves differently in space during these two periods: the horizontal Component 1 (1956–1999) and the vertical Component 2 (1999–2021). In particular, the analysis highlights a clear distinction between urban and rural locations in Component 2, with urban areas trending upwards and rural areas trending downwards. This suggests that the slow dynamics characterizing the years from 1999 to 2021 discriminate between urban and rural areas, and COVID-19 seems to have accentuated this differentiation between 2019 and 2021. More specifically, COVID-19 led to extreme demographic dynamics, confirming what has been highlighted in the previous results.



(**a**)



(**b**)

Figure 5. Loading plot (**a**) and score plot (**b**) of a principal component analysis carried out on the natural balance observed in 115 municipalities of metropolitan Athens by year and urban (black dot)/rural (red cross) status; the horizontal axis (Component 1) explains 78.2% of the total variance; the vertical axis (Component 2) explains 7.9% of the total variance.

4. Discussion

The literature has shown how exogenous events, like pandemics, can shake up the development path of regions and cities around the world [42–44]. With this perspective in mind, we investigated how the linkage between population dynamics and local development really affects how attractive and economically successful regions and cities are [45–47]. Focusing on metropolitan Athens as a case study, the research digs into such questions using a five-step approach [48–50]: (i) diving deep into the literature from different fields like demographics, sociology, economics, and geography; (ii) analyzing demographic indicators through a boxplot to check how things like the median, main percentiles, and differences in space are spread out; (iii) looking at the actual numbers of these indicators, and especially comparing urban and rural areas and how they vary; (iv) calculating selected distributional metrics; (v) using a principal component analysis to reduce multi-collinearity and extract relevant dimensions of change [51–53].

From this perspective, the COVID-19 pandemic was studied as an additional factor adding to already existing trends (in line with—or possibly following—the second demographic transition in Greece and the 2007 Great Recession). By adding new materials and statistical evidence, we verified if COVID-19 has, at least indirectly, accelerated the long-term demographic dynamics of the natural balance (i.e., natural population growth rates), considering fertility and mortality together [54]. With this perspective in mind, we performed a long-term analysis of demographic dynamics that includes the COVID-19 pandemic, the Great Crisis, and other relevant stylized facts of the last 70 years. Results outlined that past and present dynamics were affected by a plethora of factors leading to urban shrinkage, possibly associated to a latent demographic decline in metropolitan Athens. In addition to the Great Recession, the study thoroughly discusses the contribution of COVID-19 to these dynamics, demonstrating that the present and future trends of a traditionally growing and young city like Athens are shifting toward aging and population reduction. COVID-19, with direct and indirect effects (irrespective of their intensity) on fertility, mortality, and migration (e.g., reducing foreign immigration or stimulating emigration), is clearly coherent with the effect of the previous recessionary shocks and delineates a sort of negative trend accelerating past demographic dynamics and causing urban decline [55–57]. The empirical findings are discussed in light of urban theory and may inform policies for the sustainable development of cities.

More specifically, the statistical analysis run on natural balances suggests that the COVID-19 pandemic has impacted local population dynamics, showing short-term effects (increased mortality), medium-term effects (more volatile migration flows), and long-term effects (declining fertility) [15,37,38]. The extent to which these effects will affect future demographic trends is under investigation (for instance, [53–55]). Table 5 indicates a scenario characterized by low demographic dynamism in the study area. There is a noticeable slowdown of the natural population balance in downtown Athens, with a further decline in the metropolitan area both in 2022 and 2023. Specifically, Greece displays even lower values, around 0.5, signaling a ratio of two deaths for every live birth [58]. Analyzing the relationship among these variables suggests a declining population trend in the metropolitan area and a latent stabilization at the regional and national levels [59].

Table 5. Recent trends over time in the crude natural population balance (total number of births in total number of deaths) of Greece, by year and region, as derived from the national population register (Ministry of Internal Affairs); provisional data for 2023.

Year	Downtown Athens (A)	Metropolitan Attica (B)	Greece (C)	B/A Ratio	C/B Ratio
2013	1.38	1.31	0.91	0.95	0.69
2014	1.64	1.20	0.82	0.73	0.68
2015	1.62	1.11	0.76	0.69	0.68
2016	1.83	1.14	0.79	0.62	0.69
2017	1.80	1.02	0.72	0.57	0.71
2018	1.86	1.03	0.72	0.55	0.70
2019	1.75	0.98	0.68	0.56	0.69
2020	1.65	0.95	0.65	0.58	0.68
2021	1.23	0.88	0.59	0.72	0.67
2022	1.23	0.8	0.54	0.65	0.68
2023	1.23	0.8	0.55	0.65	0.69

These data hint at limited prospects for a post-COVID demographic recovery in the short and medium terms. It is crucial to implement fertility support policies to mitigate these prospects, instead of solely relying on migration flows, which currently lack significant dynamism. The solution lies in integrated policies that impact the sustainable development of the entire area, recognizing the social disparities previously discussed. To achieve this, a deeper exploration of the relationship between economic expansion and population growth is essential to understand how to implement sustainable economic development in a context of demographic decline. This aims at preventing rapid economic–demographic processes that may create disequilibria in local systems.

Long-term demographic trends, combined with the short-term pandemic effects, have been demonstrated to cause a rapid (and possibly destructive) impact on cities, leading to local depopulation and accelerating economic shrinkage. Today, many cities in advanced economies seem to represent a 'demographic laboratory' where urban centers appear as production spaces undergoing dynamics already observed in rural areas, e.g., 30 or 40 years ago. With the economic engine of cities slowing down, local development requires policies targeting activity decline and avoiding negative demographic impacts on the whole economy. Although this study investigates the case of Athens, its conclusions may apply to similar cities in Greece, Italy, Portugal, and Spain, although with some exceptions, such as Madrid and Barcelona in Spain or Milan in Italy. These latter cities might have different demographic dynamics, maintaining greater economic and demographic resilience compared to other (smaller or weaker) cities with latent shrinkage.

The limitations of this study primarily stem from the information gap, namely, the short time series representing demographic dynamics during the COVID-19 pandemic [54]. Despite providing valuable information, the empirical results presented in this study should be taken as preliminary, being especially relevant for informing short-term policies [55]. Any strategy aimed at addressing medium- and long-term dynamics requires a comparative interpretation of trends based on longer time series [56]. This logic justifies a thorough improvement of demographic indicators and official statistics [57]. In this perspective, our work contributes to refining interpretative frameworks for Mediterranean cities that are coherent with evidence gathered on broader spatial scales in Europe [58]. Clarity on how external impacts can interact with socio-demographic dynamics to shape regional development and local competitiveness, attractiveness, and sustainability contributes to delineating the intrinsic mechanisms underlying economic growth.

5. Conclusions

By developing a mixed perspective that integrates long-term with short-term analysis, we explored and discussed the long-term sustainability of urban growth paths and the underlying mechanisms of metropolitan expansion (or decline) vis à vis exogenous shocks, considering the specific impact of the 2007 Great Crisis and the COVID-19 pandemic in metropolitan Athens, a socially fragile and economic depressed region in Southern Europe. Assuming a non-neutral spatial effect, the Great Recession exerted a relatively heterogeneous impact on local development paths. Moreover, the medium-term impact of the COVID-19 pandemic on cities and regions in Europe, despite the mess of qualitative and quantitative information collected in the last years, remains largely unexplored. Both urban and rural districts within metropolitan regions—likely the most dynamic areas in any country—might face significant pressures due to the combined effect of delayed births (or reduced fertility) and increased overall mortality. This was observed during both the Great Recession and the COVID-19 pandemic, although their impact was, overall, indirect and mixed.

However, these cumulative effects add to a background (long-term) population trend typical of the last phase of the second demographic transition in advanced economies and featuring population aging, all-time low fertility, and unexpected increases (or declines) in migration flows, determining unwanted (and largely unplanned) volatility of the migratory component of the population balance, likely the most powerful component shaping urban growth in the last decades. Unemployment and increased poverty rates, as a consequence of major economic crises (namely, long- and medium-term impacts), added to the background socioeconomic context, consolidating the decline of internal and international immigration flows and boosting emigration. The reduced attractiveness of cities during pandemics (namely, short-term impacts) often enhanced the intensity of this process locally. Analyzing the multiple dimensions of socio-demographic resilience enables estimating the adaptive capacity of local systems against external shocks. With this perspective in mind, population trends may reflect socioeconomic disparities better than other indicators do, informing targeted strategies toward cohesive and balanced regions.

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