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Residential segregation in Southern European urban areas: unravelling neighborhood effects and ethnic disparities in the city of Catania (Italy)

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Abstract

This study examines the dynamics of residential segregation in Catania, a prominent urban center in Southern Italy, between 2011 and 2021. Employing Theil's entropy-based H index and Shapley decomposition, segregation trends are analyzed at both micro and macro spatial levels, using two classifications: municipal districts and Urban-to-Extra-Urban (UEU) zones. Results reveal a duality in segregation processes, with micro-spatial level desegregation for all population sub-groups offset by macro-spatial level clustering of migrant populations, especially, of Bangladeshis and Sri Lankans. In shaping these patterns, the study highlights the pivotal role of Italians' resettlement in the spatial clustering of migrant populations. By providing a nuanced distinction of subpopulation specific contributions to segregation changes, findings underscore the importance of targeted urban policies, including affordable housing and improved infrastructure, to mitigate segregation. The study enhances comprehension of spatial assimilation and stratification dynamics, offering actionable insights for policymakers and urban planners. Future research should apply the proposed method to other cities to build a comparative framework to address socio-spatial inequalities in Southern Europe.

Keywords: entropy; residential segregation; segregation decomposability; spatial demography; Southern Europe

INTRODUCTION

In many Southern European cities, stark socioeconomic disparities coexist with varying levels of residential segregation. Arbaci's (2019) "urban diaspora" framework elucidates how immigrant groups, marginalized in housing markets, are increasingly displaced from city cores to metropolitan peripheries. These processes, characterized by rising inequality and declining segregation indices, highlightthe complexity of segregation patterns in Southern Europe (Bergamaschi et al., 2021; Costarelli and Mugnano, 2017). A significant body of empirical research has explored the issue of ethnic segregation within the Italian context (Benassi et al., 2023; Bitonti et al., 2023a; Bitonti et al., 2023b; Casacchia et al., 2012; Marra et al., 2020; Mazza and Punzo, 2016; Petsimeris, 2018; Rimoldi and Terzera, 2017; Strozza et al., 2016). These studies assert that the spatial clustering of ethnic groups in urban areas derives from the interplay of two key factors. First, strong social networks, primarily built on close-knit ties, play a critical role in fostering spatial concentration (Ambrosini, 2011). Second, economically vulnerable immigrants, constrained by limited housing options, are often compelled to settle in less desirable segments of the real estate market (Davico and Mela, 1999). However, significant research gaps persist in the analysis of residential spatial dynamics, both within urban areas and between major urban centers, due to their evolving demographic composition (Buonomo et al., 2024). This study seeks to bridge these gaps by offering empirical insights into

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population changes and spatial segregation dynamics, focusing on Catania. This city stands out as one of the most emblematic urban centers in Southern Europe, as it is the second largest municipality on the island of Sicily, both by area (km2) and population (total of inhabitants), and representing the main industrial, logistical, and commercial center of the island.

The analysis adopts a methodological framework inspired by the pioneering techniques introduced by Elbers (2024) for studying residential segregation across U.S. metropolitan areas. These methods have been adapted to address the unique socio-spatial characteristics of Catania. Specifically, segregation at both micro and macro spatial levels is examined by applying Shapley's decomposition (1953) of Theil's Information Index-H (Theil, 1967, Theil and Finizza, 1971), using population census section data, through two classifications: i) a historical-administrative scheme based on municipal districts; ii) Urban-to-Extra-Urban (UEU) zones, derived from a functional framework structured along an urban-to-extra-urban continuum. This dual classification enables the generation of entropy-based segregation estimates, offering a granular understanding of segregation dynamics by native and migrant populations, within the urban area.

The contribution of this study to the literature on residential segregation dynamics is twofold. First, it evaluates whether segregation trends align with spatial assimilation theory, when decreasing micro-level segregation may signal integration, or with the stratification perspective, marked by sustained or growing macro-level segregation. Second, it investigates the marginal contributions of native and migrant[5] populations to temporal shifts in segregation patterns, engaging with a burgeoning body of literature that examines ethnic and demographic geographies. By leveraging Shapley's decomposition, the analysis elucidates how segregation patterns are shaped by population changes, providing critical insights into the roles of different immigrant communities in these dynamics.

The paper is structured as follows: the subsequent section illustrates the evolution of the theoretical studies focusing on residential segregation. The third one offers a comprehensive overview of the study context. The fourth section details the data sources and explains the methodological framework, emphasizing its adaptation to the Southern European setting. The fifth section presents the empirical results of the analysis. The final section discusses the broader implications of these findings, situates them within the existing body of literature, and proposes directions for future research.

SCIENTIFIC DEBATE ON RESIDENTIAL SEGREGATION IN EUROPE

The phenomenon of residential segregation has long been a focal point of investigation within the social sciences, since residential decision significantly influences various aspects of individuals' life, such as their social network, educational opportunities, employment prospects, health outcomes, availability of government and social services, and social capital (Morenoff, 2003; Sampson et al., 2008; Peterson and Krivo, 2010; Quillian, 2012; Kramer and Kramer, 2019; Siegel et al., 2024). It is shaped by a complex interplay of factors, primarily socioeconomic variables such as race and income disparities, alongside structural characteristics of urban environments (Massey et al. 1991; 1994). Residential segregation is not a static phenomenon but evolves over time, with changes in segregation intensity and scale influenced by migration patterns and urban development processes (Spierenburg et al., 2024). Consequently, ethnic residential segregation can stand as a significant barrier to achieving ethnic equality, yet its identification and analysis can be complex and challenging.

[5] It should be noted that in the following sections the term "migrant" is applied inclusively to denote all foreign residents, encompassing immigrants' descendants, individuals born in the destination country with parents' foreign citizenship at birth. This broader definition aligns with sociocultural and legal perspectives on migration (Vertovec, 2007; IOM, 2019).

The 'modern' study of residential segregation originated in North America during the 1920s, with the Chicago School conceptualizing segregation as a phenomenon reflecting the spatial isolation (i.e., physical distance) between social groups (Park, 1928). This theorization initiated a broader scholarly debate, predominantly influenced by the ecological perspective, which framed segregation as a temporary phase in the assimilation of immigrant groups into urban settings. Afterwards, the academic discourse shifted to the selection of the criteria for measuring physical and social distance among subpopulations. The proposed methods made extensive use of indices, like Duncan's dissimilarity index (Duncan and Duncan, 1955) and the isolation index (Bell, 1954), usually reflecting a particular dimension of residential segregation in urban contexts (James and Taeuber, 1985; Massey and Denton, 1988; Reardon and O'Sullivan 2004).

Whereas U.S. segregation is often framed as an aggregate consequence of individual choices based on racial identity (Clark et al., 2015), European discourse frequently conceptualizes segregation as a structural issue, prompting state-led efforts to mitigate its effects, particularly in housing and labor markets (Malmberg et al., 2018).

European researchers have concentrated on cultural differences and issues of citizenship, while also accounting for the influence of former colonies and post-colonial relationships. Overall, socioeconomic and class-based disparities play a more prominent role in Europe (Wacquant, 2007). The presence of welfare states in Europe has functioned as a mitigating force, curbing the emergence of homogeneous ethnic enclaves, though not without contradictions (Andreotti et al., 2012). The concept of the "state–market–family nexus" adapted from Esping-Andersen's welfare regime framework, provides a compelling lens to understand this dynamic (Arbaci, 2019). Based on both socioeconomic factors and ethnic clustering, empirical research suggests that immigrants tend to settle in urban areas (Musterd, 2005; Bergamaschi, 2012; Consolazio et al., 2023). Recent studies have highlighted the heterogeneity of segregation patterns across European cities showing significant spatial disparities among different nationalities, driven by variations in socioeconomic status (Martori and Madariaga, 2023).

A unified European model of residential segregation remains challenging, given the diversity in national systems, colonial legacies, and the geographic origins of migrants across European countries (Bergamaschi et al., 2021: 153). In the Central and Northern European cities, residential segregation results in higher spatial separation compared to the southern contexts, as the consequence of a) immigration history and patterns; b) housing market, urban planning, and welfare. As a matter of fact, immigration flows are a relatively recent phenomenon affecting urban areas in Southern Europe intensifying primarily from the 1990s onward. Immigrants in these regions tend to settle in the outskirts of large cities or in neighborhoods already characterized by high population density and low rental costs (Benassi and Salvati, 2020). In these countries, including Italy, migration flows have gained significance only in recent decades (Ambrosini, 2011: 62). As a result, the patterns of urban settlement among foreign populations are continuously evolving, necessitating ongoing observation to fully grasp their dynamics (Benassi et al., 2023; Consolazio et al., 2023). Conversely, Central and Northern Europe experienced earlier waves of immigration, starting in the 1960s with policies aimed at recruiting foreign workers (e.g., Gastarbeiter in Germany). As a result, cities in Northern Europe exhibit more entrenched and structured ethnic segregation, supported by regulated welfare systems and housing markets (Arbaci, 2007; 2008). Overall, urbanization processes intertwined with international immigration are reshaping the landscape of European cities, which are increasingly gaining prominence for their ethnic and cultural diversity. The migration histories of cities significantly affect these patterns, attracting diverse groups of immigrants from varying origins (Logan et al., 2004). International migration plays a pivotal role in transforming urban spaces socioeconomically and demographically, stimulating debates on integration and discrimination (Bolt et al., 2010; Musterd and Ostendorf, 2009). As a result, the spatial distribution of ethnic minorities has been extensively studied to identify potential negative consequences, such as social inequality (van Kempen and Bolt, 2012). Differences in housing markets, urban planning, and welfare systems further

accentuate these dynamics and exacerbate the North-South duality in Europe. In Southern Europe, homeownership predominates, and there is a limited supply of public housing compared to Northern Europe. This reduces immigrants' access to social housing and forces them to rely on the private rental market, where housing options are often less expensive but of poorer quality (Benassi et al., 2019). Consequently, the fragmentation of the housing market fosters a less visible yet pervasive form of segregation, linked to precarious living conditions rather than outright spatial division. In contrast, Central and Northern Europe feature more developed and regulated social housing sectors, which tend to concentrate migrant populations in specific areas. The greater availability of public housing results in a more pronounced spatial segregation (Arbaci, 2007).

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THE CASE OF STUDY: CATANIA

In the late 1970s, Catania began to attract flows of individuals from the world's poorest regions, seeking employment in domestic work, the restaurant industry, street vending, and other low-skilled services offered by the city (Altavilla and Mazza, 2008). Over time, Mauritians, Sri Lankans, and Filipinos have predominantly engaged in domestic work; Senegalese and Moroccans in street vending; Tunisians in agricultural work or low-skilled tertiary sector jobs; and Bangladeshis and Chinese in the restaurant industry and trade. These sectoral labor specializations were shaped by the diverse logistical needs of occupational categories and the varying opportunities for integration (such as, individuals' economic status and housing market barriers), and led to different settlement processes within the urban territory (Altavilla and Mazza, 2008). For instance, previous studies have highlighted a high concentration of foreign residents in urban sub-areas associated with affordable housing availability or workplace proximity (Mazza and Punzo, 2016; Mucciardi et al., 2017).

The population residing in Catania increased from 296,683[6] to 300,356 between 2011 and 2021. Over the same period, the share of the foreign population increased from 2.6 to 4.5 percent. The largest sub-groups of the foreign population remain the same, but the origin-composition changed.

As of 2021, Bangladeshis, Chinese, Mauritians, Romanians, and Sri Lankans collectively accounted for 56.0 percent of migrants in Catania, compared to 76.3 percent in 2011. This decline, coupled with the increase in foreign population, highlights a trend toward increasing ethnic diversity within the city's population (Figure 1), confirmed by the Shannon's diversity index rising from 0.22 in 2011 up to 0.36 in 2021.

The municipal territory of the city of Catania is divided into six districts corresponding to the six "*circoscrizioni*". The districts are associated with specific administrative activities (elections, basic services) fulfilling the needs of decentralization.

Figure 2 here illustrates the geographical layout of Catania's districts identified by cardinal numbers, which are key to understanding the distribution of migrant communities across the city.

[6] Source : https://demo.istat.it/app/?i=RCS&l=it

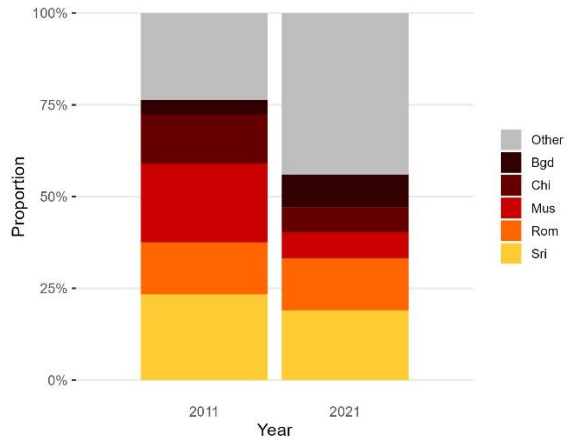


Figure 1 Foreign population composition by citizenship in the city of Catania, as for 2011 and 2021 (percentages of total foreign population). Note: 'Bgd': Bangladeshis; 'Chi': Chinese; 'Mus': Mauritians; 'Rom': Romanians; 'Sri': Sri Lankans.

District 1 is marked by its central location and its role as the city's historic, touristic, and political-administrative center. This includes the central business area and the largest outdoor market in Catania, both of which attract a significant number of migrants seeking employment in retail and informal trade. In contrast, the northern districts (2 and 3) are home primarily to the Italian middle and upper-middle classes, residing in buildings that were constructed during the 1950s and 1960s. These neighborhoods are characterized by higher property values and better access to public services. The southern and western districts, on the other hand, have been less affected by immigration and remain predominantly inhabited by locals (Mazza and Punzo, 2016).

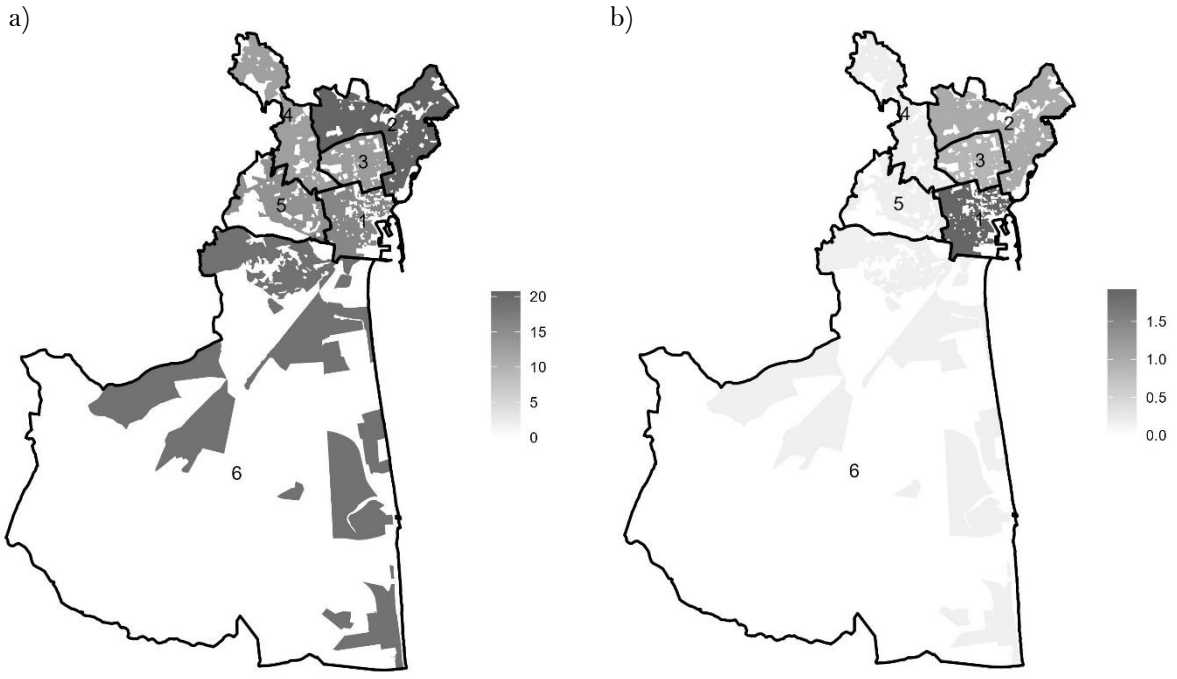


Figure 2 Italians' (panel a) and foreigners' (panel b) percentage proportions over the total population in Catania **by census sections**, 2021. Note: districts' borders are in black solid lines. Source: Italian General Population and Housing Census.

Segregation dynamics and their evolution between the two censuses are analyzed through two spatial classification systems. The first is based on the municipality's historical and administrative districts, discussed earlier.

The second spatial classification adopted in the analysis, termed Urban-to-Extra-Urban (UEU) zones, organizes the city into five typologies: Central, Semi-central, Peripheral, Suburban, and Extra-urban areas (Figure 3). These zones stem from the Real Estate Market Observatory's (OMI) framework, developed by the Italian Revenue Agency to reflect urban differences in property value and intended use.

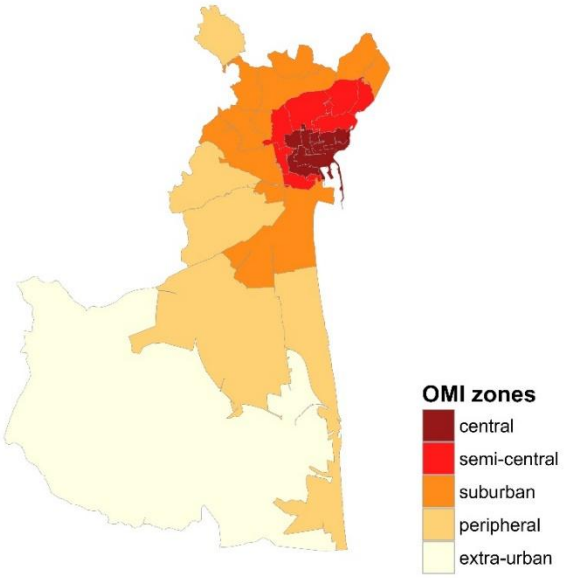


Figure 3 UEU classification in the city of Catania.

The criteria underlying UEU classifications consider centrality, accessibility to facilities and services, transportation quality, and the availability of key infrastructures, including educational, healthcare, and commercial facilities (Festa et al., 2018). It should be noted that the selection of administrative territorial subdivisions, i.e., districts, aligns with the methodological approach (Section Data and Methods) outlined by Elbers (2024), which is grounded in the official US classification of metropolitan and non-metropolitan areas.

Central areas exhibit high population density and a concentration of economic and social activities, while semi-central zones serve as transitional spaces combining urban and residential functions. Peripheral areas, typically residential, are further from the city center with reduced access to services. Suburban zones consist of low-density developments at the urban fringe, while extra-urban areas encompass rural or underdeveloped regions with minimal urban infrastructure.

The two classifications provide complementary lenses for analyzing segregation. The district-based framework emphasizes historical and administrative boundaries, whereas the UEU zones highlight spatial and socioeconomic dimensions. These different criteria may reveal distinct segregation patterns and dynamics.

DATA AND METHODS

This study examines segregation patterns using cross-sectional data from two census years, 2011 and 2021. The stability of census section boundaries over this period eliminates concerns about geographic harmonization. The analysis relies on datasets from the Italian General Population and Housing Census for these years, focusing on the five largest migrant groups in Catania: Sri Lankans, Romanians, Mauritians, Bangladeshis, and Chinese. All analyses were conducted using R 4.4.2, including a number

of open-source packages, and were based and adapted from the source code created by Elbers (2024) and freely available online.

Segregation as the social counterpart of entropy

Segregation, defined as the spatial separation of population sub-groups within a larger geographic region, is studied using various indices that address its multidimensional nature (Massey and Denton, 1988; Winkler and Johnson, 2016). Residential segregation is analyzed here through information-theoretic approaches, specifically entropy, and its derivative measures. Entropy, originating in physics and adapted to information theory, measures randomness or informational complexity within a system (Shannon, 1948; Coulter, 1989; Cover and Thomas, 2006). Theil (1967, 1972) pioneered its application to social sciences, using entropy to study population diversity and inequality (Reardon and Firebaugh, 2002; White, 1986).

In the context of segregation, entropy quantifies the heterogeneity of population distributions across spatial units. Considering a) on the one end residential segregation is the non-random distribution of individuals over space based on their group identity, and b) entropy as the randomness of distribution of groups of individuals on the other, entropic measures are conceptually and mathematically ideal to measure local and regional residential segregation (Kramer and Kramer, 2019). In the present application, Theil's H index (Theil, 1971; Theil and Finizza, 1971), grounded in entropy, serves as a robust metric for analyzing residential segregation in Catania.

Using a matrix **T** with U rows (representing spatial units, e.g., census sections) and G columns (denoting population groups), pairwise H indices are computed for Italians to compare each selected migrant group. The entries of **T**, t_{ug}, represent the number of individuals from group *g* in spatial unit *u*. The total population is $t = \sum_{u=1}^{U}\sum_{g=1}^{G} t_{ug}$, and joint probabilities of being part of the group *g* and being in spatial unit *u* are calculated as $p_{ug} = t_{ug}/t$. Marginal probabilities for spatial units and groups are $p_{u\cdot} = \sum_{g=1}^{G} t_{ug}/t$ and $p_{\cdot g} = \sum_{u=1}^{U} t_{ug}/t$, respectively. The H index is expressed as:

$$H(T) = \frac{100}{E(T)}\sum_{u}\sum_{g} p_{ug} log \frac{p_{ug}}{p_{u\cdot}p_{\cdot g}}$$

Here, $E(T) = -\sum_{g=1}^{G} p_{\cdot g} log p_{\cdot g}$ is the entropy of the population group's marginal distribution. The H index ranges from 0 (no segregation) to 100 (complete segregation).

As stated by Reardon et al. (2008), "there is no single geographic scale of segregation". Segregation operates on multiple levels simultaneously, spanning from individual households to neighborhoods and entire countries. The scale at which segregation is analyzed significantly affects the methods used for its measurement and representation. Furthermore, the underlying dynamics of segregation (i.e., the factors that both produce and sustain it, along with its socioeconomic and cultural outcomes) vary depending on the scale of analysis (Kaplan and Holloway, 2001). Given the "inherently scalar nature" of segregation (Kaplan and Holloway, 2001), there is no single geographical scale of segregation as well as no "correct" scale for studying it and its changing patterns (Fowler, 2016). For this reason, it is useful to employ additively decomposable segregation indices, which, for any partition of organizational units into clusters or population groups into supergroups, enable the overall level of segregation to be expressed as the sum of two components: one representing segregation between groups and the other reflecting segregation within groups (Mora and Ruiz-Castillo, 2011). This approach, widely used in U.S.-based studies (e.g., Fischer et al., 2004; Reardon et al., 2008), offers a geographically nuanced perspective on segregation, capturing both micro- and macro-level dynamics (Lee et al., 2008): micro-segregation occurs at localized scales, such as within census sections, while macro-segregation reflects broader spatial patterns, such as between districts or metropolitan zones (Winkler and Johnson, 2016). Maloutas and Karadimitriou (2022) define urban micro-segregation as the existence of socioeconomic or ethnic inequalities within areas smaller than neighborhoods. This

concept is essential for understanding socio-spatial hierarchies that persist at the micro-area level, even in neighborhoods that exhibit social diversity (Maloutas and Karadimitriou, 2001). The H index can be decomposed into macro and micro components, where total segregation is expressed as:

$$H(B) = H_{macro}(B) + H_{micro}(B).$$

Here, H_{macro} reflects segregation between districts (or UEU zones), while H_{micro} captures within-district (or UEU zones) segregation as a weighted sum of localized H indices (Elbers, 2024).

The Shapley decomposition: single foreign population sub-group's contribution to segregation change

Changes in segregation levels may arise from shifts in group distributions across neighborhoods. The Shapley decomposition (Shapley, 1953), rooted in cooperative game theory, provides a framework for attributing segregation changes to specific groups. For instance, consider a specific area where the population is divided into two distinct groups. By holding the population distribution of one group constant over time while allowing the size of the other group to vary, it becomes possible to isolate the unique impact of the latter on the entropy-based segregation index, H. The Shapley decomposition method effectively captures this distinct contribution and can be formulated as detailed in Elbers (2024):

$$I = v(N) - v(\emptyset) = v(\{1,2,\dots,m\}) - v(\emptyset)$$

where I, the outcome of interest, here is considered as the variation in segregation between time 1 and 2; $v(N)$ measures segregation at time 2, $v(\emptyset)$ measures segregation at time 1, and $N = \{1,2,\dots,m\}$ is the set of factors of interest, that in the present case are represented by the foreign groups and the local population. Given that certain decompositions involve an excessive number of factors, rendering a closed-form computation of the Shapley decomposition infeasible, a simulation-based approach is employed to approximate the solution, following Elbers (2024).

In this context, the Shapley decomposition is employed to evaluate how the largest migrant population sub-groups have influenced segregation dynamics by examining changes between the 2011 and 2021 periods.

This approach presents some limitations, changes in population distribution result from natural demographic processes, which involve the interplay between births and deaths, and net residential mobility, including both internal and international migration. Previous studies, such as Finney and Simpson (2009) for Britain and Wessel et al. (2018) for Oslo, have employed similar designs to isolate demographic processes influencing segregation indices. However, because datasets on spatial micro-level demographic changes for Italian municipalities are not publicly available, this study should focus on aggregate patterns to assess the contributions of each subpopulation to shaping residential patterns in Catania over time.

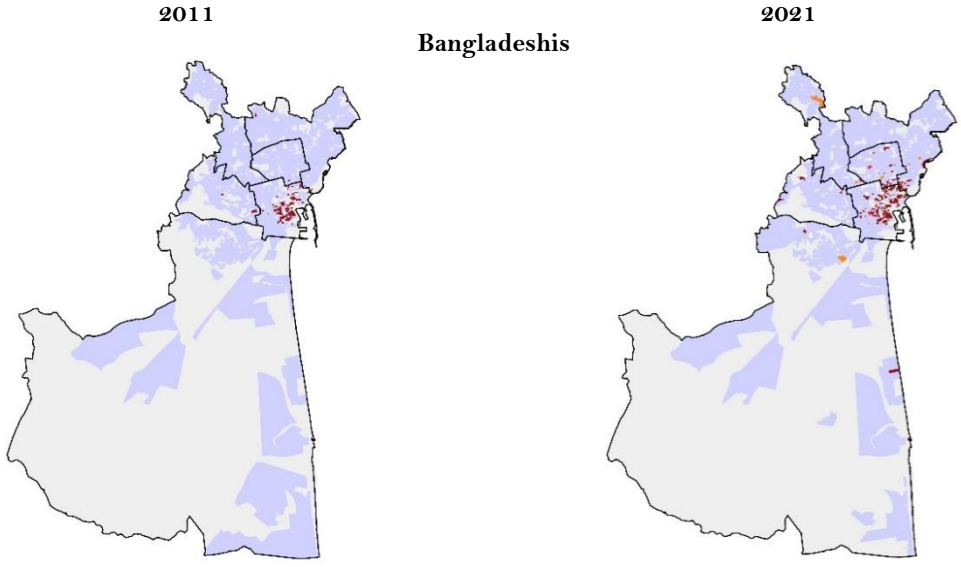
RESULTS

Among foreign groups, Sri Lankans and Mauritians display similar settlement patterns, with concentrations in both the central zone (classified as zone 2 by the UEU, corresponding to district 1 in administrative classification 1)—characterized by socioeconomically disadvantaged conditions—and the northern neighborhoods (a semi-central zone in classification 2, district 3 in classification 1) (Figure 4). This dual distribution likely reflects their predominant employment in domestic and caregiving roles within Italian households, particularly in the wealthier northern areas. In contrast, Chinese residents exhibit a distinctive clustering in the central business and commercial hubs, driven by their involvement in trade and restaurant activities (extra-urban zone in classification 2, and district 6 in classification 1). Meanwhile, Romanians show the most dispersed settlement pattern, with a notable presence in both central and semi-central zones, reflecting a broader range of occupational

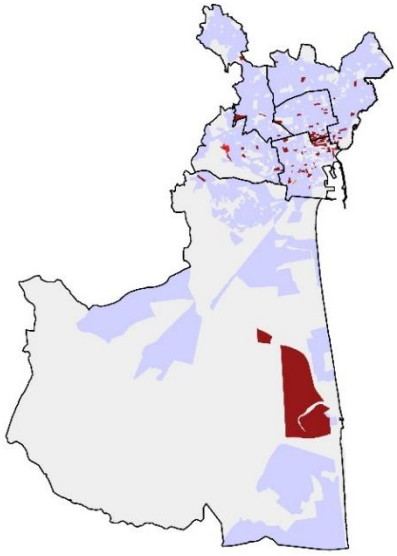
roles and housing choices. Bangladeshis, on the other hand, show a pronounced concentration in central zones with low-cost housing and proximity to informal labor markets. This pattern is indicative of their employment in sectors such as street vending, small-scale retail, and low-skilled services.

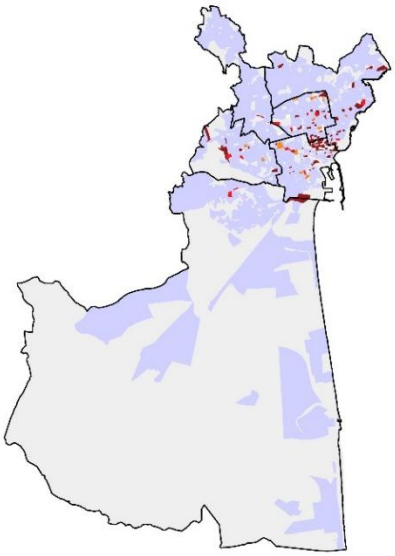
The temporal evolution of settlement patterns reveals gradual desegregation for groups such as Chinese and Bangladeshis, who have begun to expand into semi-central areas (classification 2, administrative district number in classification 1) characterized by mixed residential and economic functions. Over the decade from 2011 to 2021, there is evidence of a slow but noticeable expansion into adjacent semi-central zones. This shift may suggest an emerging trajectory of spatial assimilation, driven by gradual economic mobility and increased access to diverse housing options, though settlement patterns remain shaped by affordability and occupational constraints. Conversely, Sri Lankans, Romanians, and Mauritians exhibit a generally more dispersed settlement model that persists over time. These dynamics underscore their continued labor market specialization and reliance on low-cost housing options.

The spatial distribution of Italians and migrant subpopulations is analyzed using the pairwise H(T) indices (Figure 5), which compare the spatial distribution of Italians with that of each migrant population group separately, in 2011 and 2021. Over the 2011–2021 period, the results highlight a general decline in overall segregation levels between Italians and the migrant population, while revealing distinct integration trajectories among different sub-groups. Notably, the highest level of segregation is observed between Italians and Bangladeshis, whereas the lowest is recorded between Italians and Romanians (as also illustrated in Figure 4). This striking contrast between Romanians and the other migrant groups reflects significant progress in spatial integration, likely facilitated by Romanians' EU membership and their consequent right to free movement across Italian territories. Overall, the pairwise H(T) indices capture settlement dynamics and the influence of social networks, underscoring the role of inter-group relations and housing market constraints in shaping segregation patterns over time.

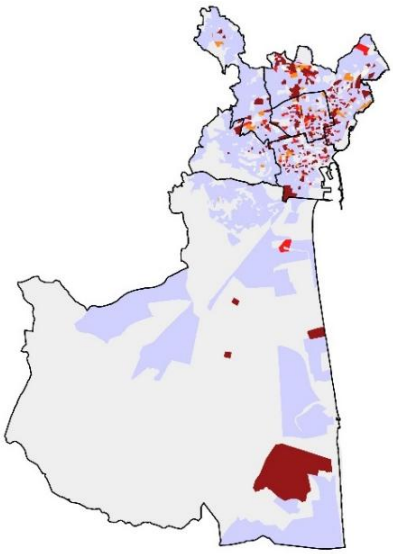


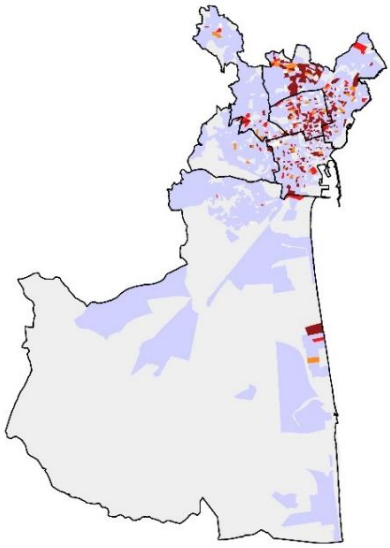
Chinese



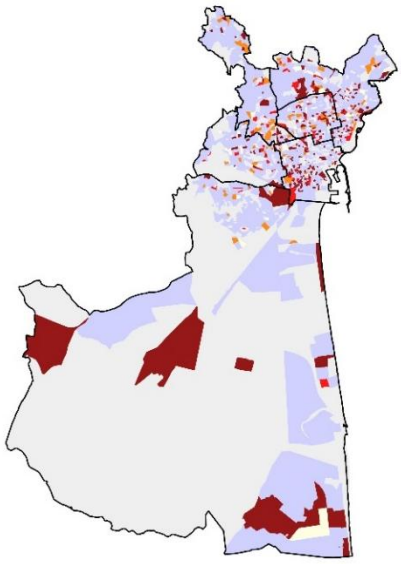


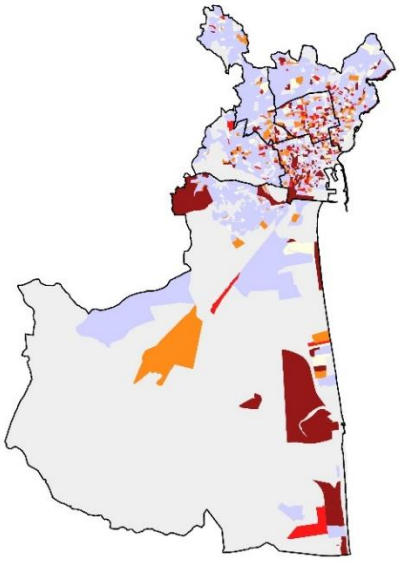
Mauritians





Romanians





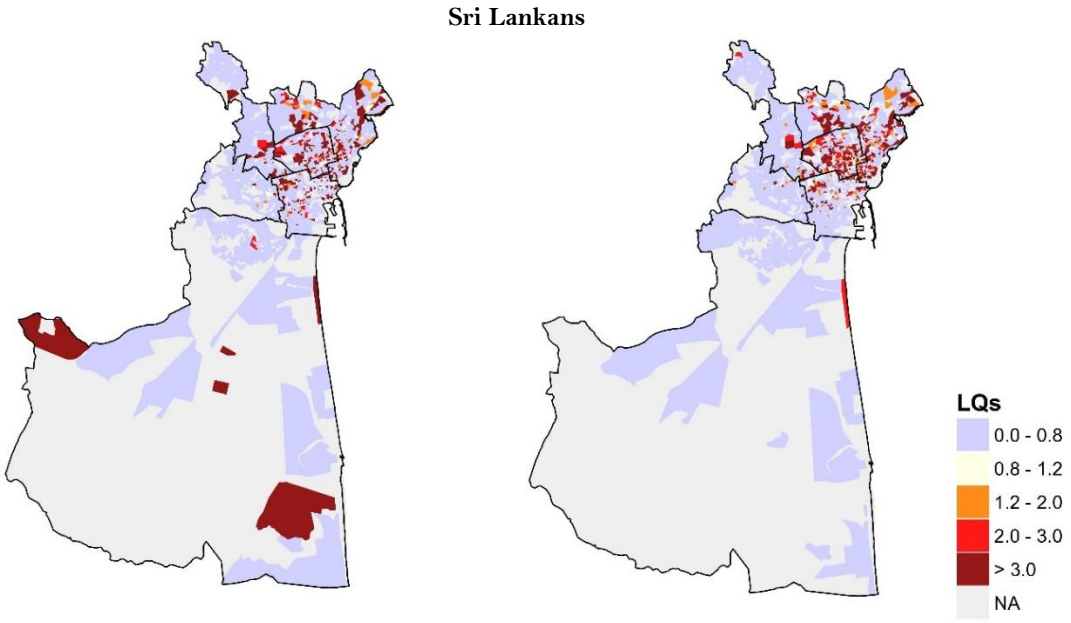


Figure 4 Location quotients (LQs) at the census section level for the largest migrant groups residing in Catania in 2011 and 2021. UEU zones boundaries in black solid lines. Reference population: Italians. Note: census sections with less than 30 inhabitants were omitted due to robustness issue of the metrics.

As outlined in the Methods section, the H index can be decomposed into macro- and micro-level components, capturing both between-district (or UEU zones) segregation and within-district variations. Figure 6 presents the cross-sectional decomposition of pairwise H(T) indices, distinguishing between these two dimensions. Meanwhile, Figure 7 applies the Shapley decomposition framework to examine the shifts in segregation between 2011 and 2021. This approach allows for the attribution of segregation changes to specific migrant sub-groups by isolating their distinct contributions. The decomposition analytically separates segregation shifts into four components: the contribution of each group in a given pair to macro-level segregation changes and their respective contributions to micro-level segregation changes.

Moderate segregation for all the migrant populations with respect to Italians is evident, regardless of the adopted geographical classification (Figure 6). However, except for Bangladeshis, whose levels of segregation increased slightly all migrant groups experienced moderate declines in total segregation over the decade with Romanians desegregating the most through time. Looking at macro and micro components, both geographical classification highlight that while macro-segregation has intensified—driven by increasing ethnic clustering across broader urban zones—micro-segregation reductions are evident within districts/UEU zones (Figure 6). In particular, central and semi-central areas account for the highest share of segregation at the micro level for all pair combinations (Italians with migrant subpopulations). This divergence indicates the simultaneous processes of diversification at the local level and stratification across larger spatial scales on the one end, and to the spatial separation between foreigners and locals in the central areas of Catania.

Figure 7 presents the Shapley decomposition of segregation changes between 2011 and 2021 for each migrant subpopulation, considering the two spatial classification frameworks: UEU zones (panel a) and municipal districts (panel b). The total change in segregation is decomposed into four components, capturing the contributions of Italians and each migrant group at both the micro- and macro-levels. In panel a (UEU zones), the primary trends reveal a substantial decrease in micro-level segregation for all the groups, except for the Chinese, suggesting the spatial redistribution of the groups across smaller spatial units within each UEU zone.

This micro-level desegregation is mostly driven by the foreign groups' dispersal into semi-central zones, while Italians contribute marginally to this decrease. Conversely, macro-level segregation increased for all the couples except that for Chinese, reflecting clustering in central zones as Italians relocated to peripheral areas. Also, in this case, the largest contribution to the increase in segregation at the macro level is mostly attributable to the foreign groups. The generalized micro-level desegregation within both UEU zones aligns with spatial assimilation theory, which suggests integration through localized mixing. However, the simultaneous increase in macro-level segregation, particularly for Sri Lankans and Bangladeshis, supports a stratification perspective, where broader geographic clustering perpetuates socio-spatial divides. Panel b mirrors some of the observations from panel a but also underscores classification-specific nuances, namely for Bangladeshis macro and micro levels of spatial segregation. Due to the internal homogeneity of the UEU zones, this classification (panel a) reports a general increase in the macro-level segregation compared to that yielded by the computation based on the districts (panel B). These differences can be interpreted as effects of the functional characteristics of the UEU clusters sub-areas, irrespective of the geographical contiguity adopted by classification 1.

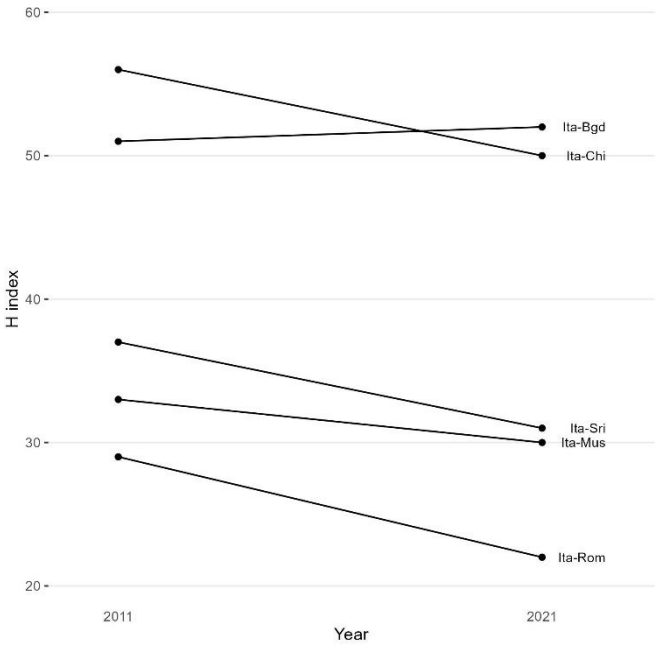


Figure 5 Pairwise segregation H(T) indices on census section level data in 2011 and 2021 in the city of Catania.

Leveraging the Shapley decomposition, Figure 8 presents a comprehensive disaggregation of macro-level segregation into distinct spatial patterns of change, by subgroup, directional shift (increase or decrease), and geographical location. This analytical breakdown elucidates to what extent large-scale residential redistributions across urban areas shape the evolving dynamics of segregation. Specifically, the detailed decomposition of macro-segregation changes between 2011 and 2021 is delineated by spatial classification into UEU zones (panel a) and districts (panel b). Each panel disaggregates the macro- level shifts into components driven by changes in group-specific distributions and locational shifts. In panel a, the increase in macro-segregation for Sri Lankans is attributed to their relocation from peripheral to central areas, coupled with Italians' movement away from central zones. For the Chinese, segregation falls due to population declines in peripheral areas and increased clustering in central and suburban areas. Romanians exhibit contrasting trends: while they desegregate in semi-central zones, their concentration in central areas partially offsets this effect. Bangladeshis' movements towards central zones exacerbate segregation, while Mauritians demonstrate a pattern of clustering that reinforces macro-segregation trends. Panel b reveals similar trends but highlights classification-specific variations. For Sri Lankans, the macro-level decrease is driven by their growing presence in northern districts (II and III). The decreasing segregation of Chinese residents stems from their reshuffling across peripheral districts. The modest desegregation of Romanians within semi-central districts contrasts with their clustering in central neighborhoods. Bangladeshis' and Mauritians' movements mirror the one observed across the UEU zones.

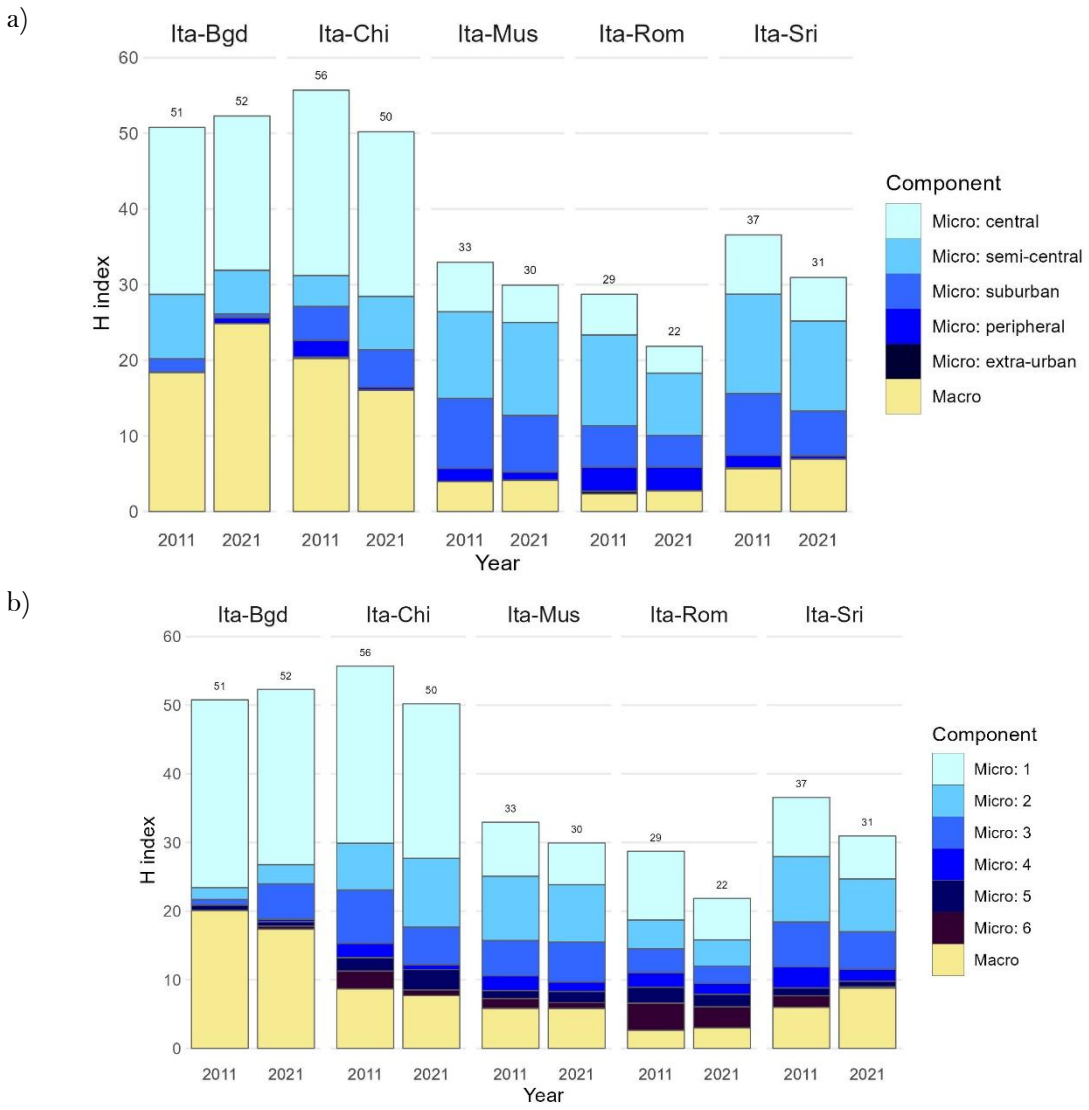


Figure 6 Pairwise (Italians and migrant subpopulations) segregation in Catania in 2011 and 2021. Total segregation is decomposed into macro and micro segregation. Micro segregation is further broken down into separate components for UEU zones (panel a) and for districts (panel b). H index values, which assess the total segregation, are reported at the top of the bar.

DISCUSSION AND CONCLUSION

This study investigates the interplay between population changes and spatial segregation in Catania. By employing a dual spatial classification framework—historical-administrative municipal districts and functional Urban-to-Extra-Urban (UEU) zones—alongside entropy-based metrics such as Theil's H index and Shapley decomposition, this research provides novel insights into the micro- and macro-level mechanisms underlying segregation trends in Southern European urban contexts.

The findings underscore the complexity of residential segregation dynamics, shaped by the interplay of micro- and macro-level factors. While declining total segregation signals progress toward ethnic integration, the divergence between micro- and macro-segregation trends reveals persistent spatial stratification. Migrants' settlement patterns, influenced by socioeconomic factors and urban planning constraints, highlight distinct trajectories of integration and segregation among groups.

Notably, the comparative analysis of territorial classifications emphasizes the importance of methodological frameworks in capturing the nuances of segregation dynamics.

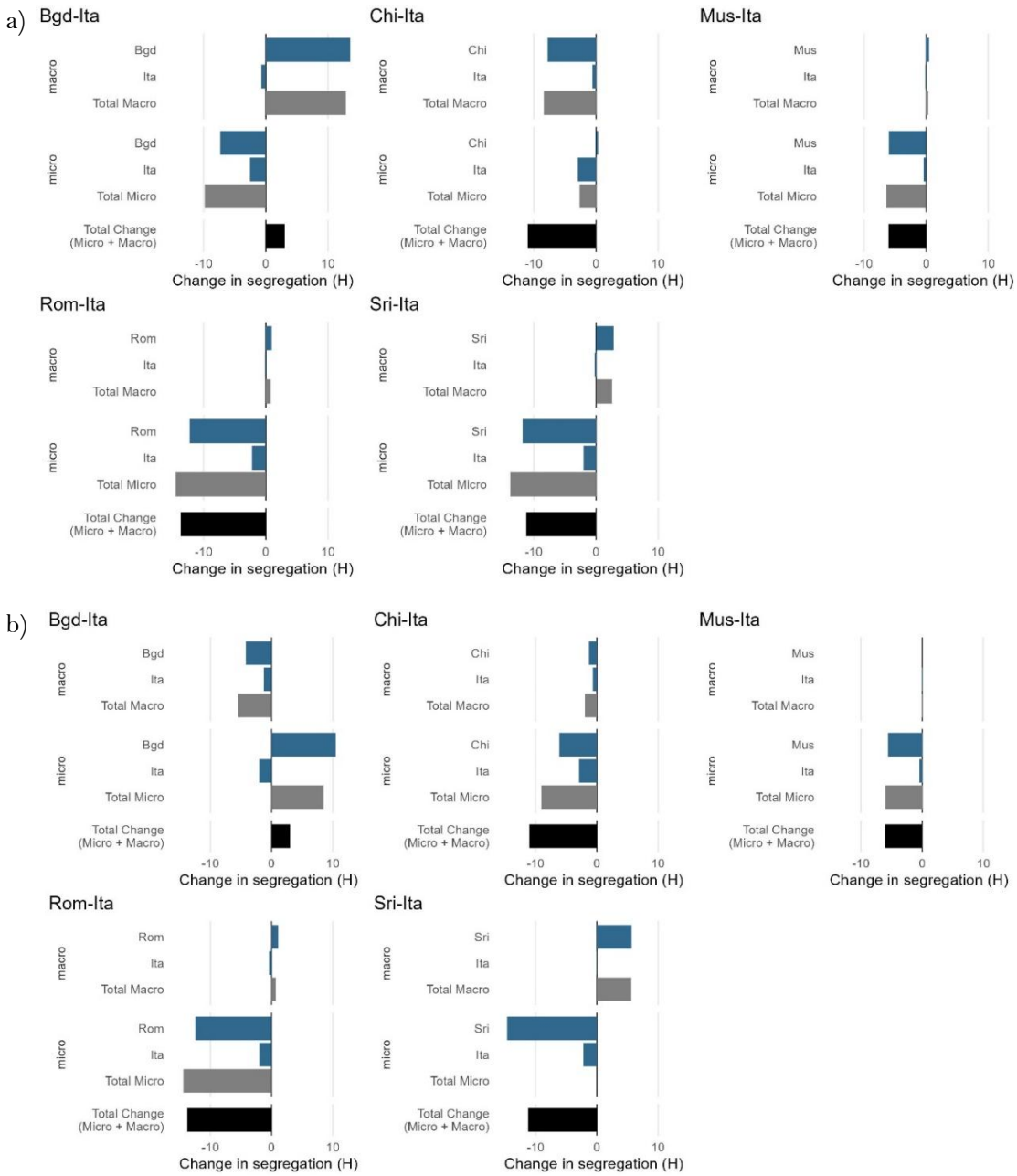
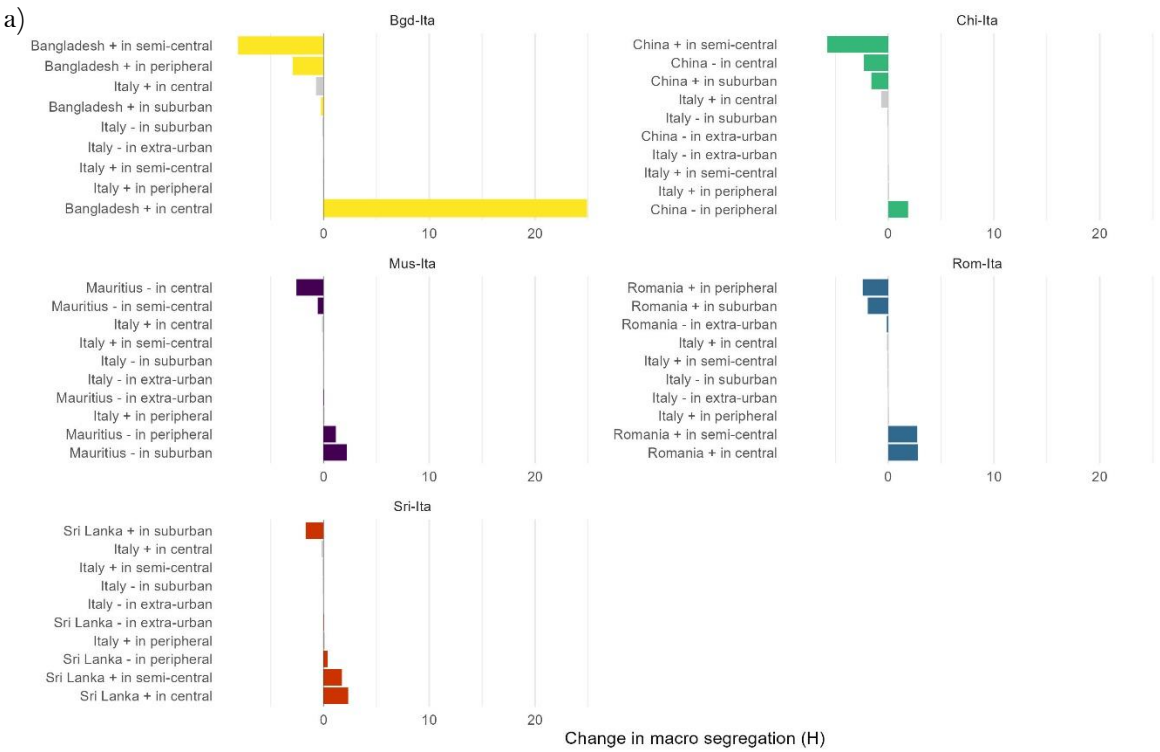


Figure 7 Pairwise decomposition of changes in segregation, 2011-2021 for UEU zones (panel a) and for districts (panel b).

The use of UEU classification allows for a comparison of our results with prior analyses conducted in Messina (Sicily) (Bitonti et al., forthcoming). Although overall segregation levels in Messina are comparatively lower, the micro-macro decomposition of segregation patterns closely mirrors that observed in Catania, where micro-level segregation predominates, indicating the presence of localized clusters of foreign residents. Moreover, whereas in Messina the spatial redistribution of Italians from the urban core to peripheral areas has significantly contributed to shifts in segregation over time, in Catania, temporal variations in segregation are primarily driven by the mobility of foreign residents, with only a marginal influence from the "re-centralization" of Italians. These discrepancies underscore the crucial role of city-specific structural and socio-demographic factors in shaping the settlement patterns and trajectories of foreign communities.



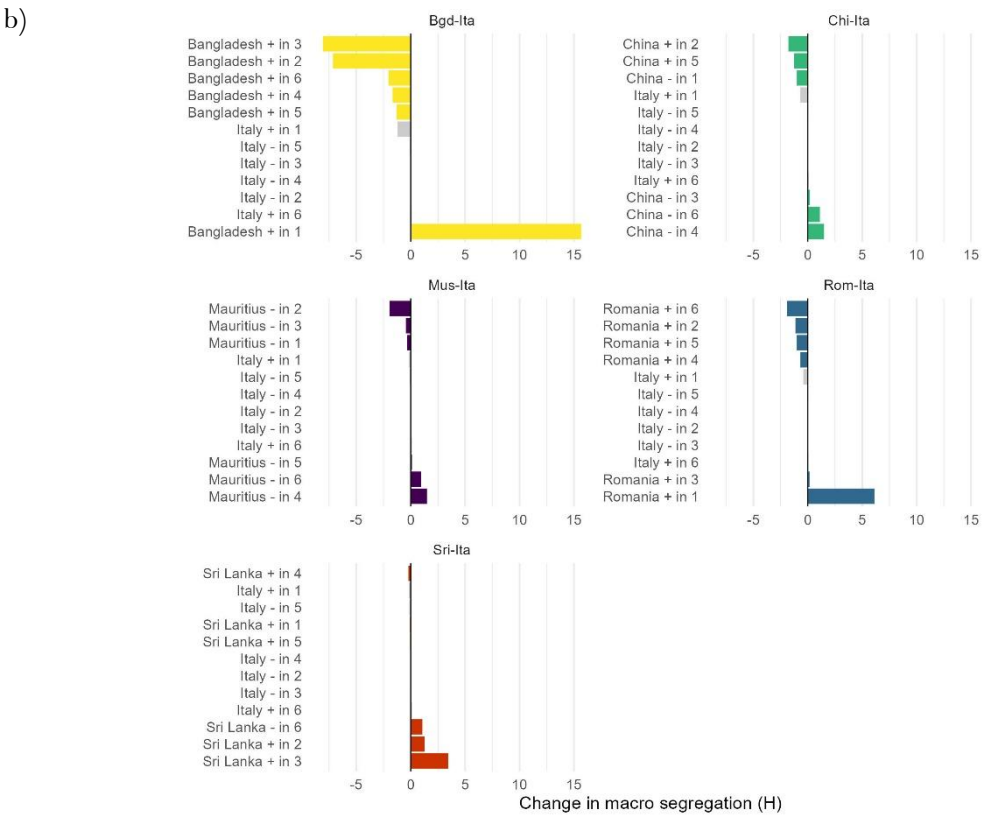


Figure 8 Detailed decomposition of changes in macro segregation, 2011-2021 for UEU zones (panel a) and districts (panel b).

These findings address significant gaps in the existing literature, particularly the shortage of granular analyses of urban segregation in Southern European cities. First, the study demonstrates that segregation dynamics in Catania exhibit both spatial assimilation and stratification characteristics, with micro-level desegregation often counterbalanced by macro-level clustering. This duality confirms the complexity of segregation processes, which cannot be fully understood without considering both localized and broader spatial patterns. This highlights how evidence of micro-level integration coexists with macro-level segregation due to socio-cultural structural barriers and spatial constraints.

Second, by isolating the contributions of specific population groups to segregation changes through Shapley decomposition, this research offers a nuanced perspective on how population distribution shifts drive segregation. The analysis reveals that the resettlement of Italians from central zones and the clustering of migrant populations in peripheral areas significantly shaped segregation patterns. These findings align with recent studies, such as Elbers (2024), that emphasize the role of group-specific mobility in shaping segregation outcomes.

Compared to prior research in Southern Europe, which has often focused on broader regional patterns, this study's methodological rigor and local specificity add a new dimension to the discourse. By adapting techniques from studies of segregation in U.S. metropolitan areas (e.g., Elbers 2024), this work bridges methodological gaps and demonstrates the applicability of these approaches in different sociocultural contexts.

Policy implications of these findings are manifold. Addressing entrenched segregation requires targeted interventions that account for both micro- and macro-level dynamics. For example, policies promoting affordable housing in central areas and improving infrastructure in peripheral zones could mitigate clustering and foster integration. Additionally, addressing systemic barriers, such as labor market discrimination and unequal access to social services, is critical to facilitating spatial assimilation. Future research should extend these analyses to other Southern European cities, enabling comparative evaluations and a more comprehensive understanding of urban segregation dynamics. Moreover, longitudinal analyses of individual mobility patterns and their intersections with housing market dynamics are needed to unravel the mechanisms driving spatial segregation further. Such insights would provide valuable guidance for policymakers seeking to enhance social cohesion and equity in rapidly diversifying urban contexts.

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Data availability statements

The data analyzed in the present work have been made available within the scope of the *"Caratteristiche, comportamenti e condizioni di vita degli immigrati di prima e di seconda generazione secondo le principali fonti disponibili"* research agreement between the Italian National Institute for Statistics (Istat), the National Research Centre (CNR), and six Italian university departments.

Declarations

The authors declare no conflicts of interest.

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