URBAN GROWTH AND POLYCENTRIC SETTLEMENTS: AN EXPLORATORY ANALYSIS OF SOCIOECONOMIC AND DEMOGRAPHIC INDICATORS IN EMILIA ROMAGNA, ITALY

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Abstract*. Urbanization in European countries has resulted in drastic changes in urban morphologies and land-use patterns due to inherent sprawl processes. To assess the shift from compact forms towards dispersed and polycentric settlements, an original procedure based on exploratory data analysis has been proposed using easily and freely available statistical indicators. The procedure has been applied to the Emilia Romagna region, considered as an emblematic case study for European regions with high levels of income and well-being, infrastructures and anthropogenic pressure on land.*

Keywords*: Urban growth, Polycentric development, Sustainable cities, Italy.*

1. INTRODUCTION

The rapid expansion of European cities, traditionally characterized by dense and compact forms, has raised attention for the impact on traditional landscapes and increased soil consumption.

In the last century, many urban areas have experienced significant changes in shape and structure, due to both the dense urbanization observed since the 1980s and the discontinuous expansion afterwards. In Italy, compact urbanization, typical of the decades immediately following World War II, preceded an urban phase with more dispersed morphologies, which transformed the traditional mosaic of rural villages and natural areas into a discontinuous, low-density peri-urban landscape (Schneider and Woodcock, 2008).

This phenomenon has been usually ascribed to the growth of large cities as well as to the consolidation of a network of medium-sized cities. However, the development of discontinuous fringe settlements outlines a 'leap of scale' in the

process of urban growth. Urban sprawl and the resulting loss of natural landscapes are problems that extend their impact beyond strictly urban regions and that require dedicated policy measures at both national and local levels (Couch et al., 2007). The negative effects of urban expansion can be cumulative and expand into progressively larger regions, reducing the system's resilience to shocks of external origin (Munafò et al., 2010).

Soil sealing is considered a typical example of urban use of land, and results in the loss of natural resources driven by urban growth and infrastructure. Within the Soil Thematic Strategy, the European Commission published an 'Overview of best practices for limiting soil sealing or mitigating its effects in EU-27' (European Commission, 2011). On the basis of this report, the European Commission has then set up the 'Guidelines on best practice to limit, mitigate or compensate soil sealing' (European Commission, 2012), collecting examples of national and regional policies, as well as planning tools, along with information campaigns implemented throughout the European Union. The guidelines are directed to the competent authorities of the Member States (at national, regional and local levels), and to the professionals in land-use planning and land management, possibly arousing interest of local stakeholders and individual citizens as well (European Environment Agency 2006).

In this sense, the form of human settlements, with particular reference to urban and peri-urban areas, has attracted the attention of social and economic disciplines. The debate on the recent transformations in the European regions, from compactness to sprawl, and from mono-centric to polycentric urban structures, has gained a renewed interest in recent times. The evaluation of these processes has benefited from a number of approaches and indicators developed from different perspectives (Hasse and Lathrop, 2003; Newman, 2005; Jaeger et al., 2010) with the aim of assessing the effectiveness of planning strategies as regards the forms of human settlements, socio-spatial and economic structures, short- and medium-term dynamics of productive activity (Tsai, 2005; Torrens, 2006). In European countries, polycentrism is an explicit target of European Spatial Development Perspective (see, for instances, European Spatial Planning Observation Network ESPON, 2014).

Aim of this paper is to introduce an exploratory procedure for the evaluation of long-term urbanization by means of freely available demographic and socioeconomic indicators. In this approach, the spatial distribution of the population and its changes over time are analyzed to verify the transition from compact to dispersed settlement patterns, inferring on the shift from a mono-centric and concentrated urban structure towards polycentric and more spatially-balanced urban configurations. The present work proposes a selection of statistical indicators

assessing the degree of population concentration and territorial changes due to different forms of urbanization (compact, dense, branched, dispersed, polycentric). Indicators were derived from a census database that evaluates the distribution of the resident population in the local municipalities of Emilia Romagna region over the last 150 years (1861-2011). Emilia Romagna has been chosen because (i) it is one of the few Italian examples of policy development actively pursuing the target of polycentrism (Cowell, 2010) and (ii) it could be considered as a case study paradigmatic for many urban regions with a high level of income and well-being, infrastructure and human pressure in Europe.

The rest of the paper is organized as follows: the following section describes the data, the indicators and the statistical methods used for the analysis; the third section presents the results of descriptive statistics and multivariate analysis; conclusions about the study performed and some policy indications are provided in the fourth section.

2. METHODOLOGY

Contrasting morphological and functional urban trends may contribute to determining the consolidation of a mixed urban model, shifting from compact and mono-centric settlements to a more branched dispersion form, resulting in an 'immature' polycentric structure based on local accessibility and flat morphology. Our results, highlighting the nexus between demographic dynamics, urban structure, economic performances and socio-spatial configurations, may represent a new contribution to the study of long-term urbanization processes in mixed urban-rural regions, with similar morphological and functional characteristics.

Data on resident population were collected at the municipal level on the basis of 1991 administrative boundaries; data referring to 2001 and 2011 were subsequently added, by checking for changes in territorial boundaries and recalculating the total resident population at the municipal level using data at the enumeration district scale. Data are derived from the population census carried out every ten years by the Italian National Institute of Statistics (Istat) from 1861 until 2011. For each studied point in time, we calculated 11 indicators from the database described above.

These indicators are aimed to verify the concentration or dispersion of the regional population and human settlements towards a progressive spatial equilibrium condition, due to recent phenomena of re-distribution of the population outside the major urban centers as a result of policies targeted at poly-centric development. These indicators elaborate the spatial series of data on resident population for each municipality of the region and for each census year (1861-2011) by identifying measures of central tendency, indexes of dispersion, skewness and kurtosis, as well as turning points in municipal time series.

Namely, we used the following indicators: (i) arithmetic mean of population density at the municipal level (inhabitants per km^2), (ii) coefficient of variation of municipal densities, (iii) range between the maximum and the minimum municipal density (inhabitants per km^2), (iv) range between the maximum and the minimum municipal density normalized to the arithmetic mean, (v) median density (inhabitants per km^2), (vi) the ratio between the median and the arithmetic mean taken as an index of non-normality of the spatial distribution of densities, (vii) skewness; (viii) kurtosis, (ix) harmonic mean (inhabitants per km^2), (x) the ratio between the harmonic and the arithmetic mean, (xi) the reciprocal of the Pearson's correlation coefficient between the series at time t and t+1. The latter indicator pinpoints the major points of discontinuity in the time series: positive values around zero indicate a substantial uniformity in the spatial distribution of the resident population at the regional level, while progressively greater (positive) values indicate increasingly deviations from the spatial distribution observed in the previous year, outlining a process of population redistribution at the regional scale.

A Principal Component Analysis (PCA) has been performed on the values of eight of the indicators described above (arithmetic mean, coefficient of variation, normalized range, median, skewness, kurtosis, harmonic mean, Pearson's correlation coefficient; three indicators were not considered to avoid redundancy) in the 15 points in time. Due to its capability to underline latent dimensions that might be demised from a traditional econometric analysis, PCA has been widely used in urban studies, e.g. in the definition of 'world cities' (Taylor and Walker, 2001), in the measurement of sprawl (Cutsinger et al., 2005) and urban fragmentation (Bereitschaft and Debbage, 2014), in the analysis of urban location of economic activities (Camacho-Ballesta et al., 2014; Cruz and Teixeira, 2015). In this study, multivariate analysis was aimed to assess the relationship between demographic indicators over time and any change in the spatial distribution of the resident population, by identifying a reduced number of latent demographic and settlement factors, as a possible contribution to the study of the evolution of the regional urban system in Emilia Romagna.

3. RESULTS AND DISCUSSION

The analysis shows that urbanization in Emilia Romagna, especially after World War II, was associated with population growth, with increasing density from 239 to 312 inhabitants per km^2 at the regional level (Table 1), but with a trend towards less rapid dynamics in recent decades (the annual growth rate averaged 0.3 % per year in the last three decades compared to 0.7% observed in the previous post-War decades).

Table 1: Selected demographic dynamics in Emilia Romagna after World War II

Variable	Year 1951	1981	2011
Population density (inhabitants per km^2)	239	290	312
Annual population growth rate (%)	0.7	0.7	0.3
Population in Bologna, regional capital town (%)	13.3	14.8	11.3
Population in the other provincial capital towns (%)	46.8	53.9	49.0

The population residing in the regional capital town (Bologna) increased in the first thirty years (1951-1981) until reaching nearly 15% of the total population of Emilia Romagna, and declined afterwards.

At the same time, the resident population in the eight provincial capitals showed a similar trend, with a marked increase in the first three decades and a reduction in the following years. In the analyzed time period, Emilia Romagna experienced both compact and dense urban growth after World War II and more subtle processes of population redistribution and rearrangement of the economic structure at the provincial level, clearly visible with the loss of primacy of the capital cities and especially of Bologna.

Table 2 shows the indicators' dynamics over the 150 years covered by the Italian censuses. Indicators outline a comprehensive picture of changes in the spatial structure of resident population in Emilia Romagna. While the central tendency, represented by the arithmetic mean calculated on 341 municipalities, increased progressively, the coefficient of variation shows a continuous growth until 1971, while declines – albeit moderately – since 1981. The same pattern can be observed for range measures. In particular, the absolute range, which reaches its peak in 1971, highlights differences of approximately 3,500 inhabitants per km^2 in population density between urban and rural municipalities. The gap drops to around 2,750 inhabitants in 2011, witnessing the slow process of spatial redistribution of the population observed in the most recent decades.

The median shows a distinct dynamic from the arithmetic mean, reaching the maximum value in 1951 and then following a negative – albeit not perfectly monotonic – trend. This is further underlined by the median-to-mean ratio which is indicative of high deviations from normality in the distribution analyzed from the years of Italian economic boom onwards (1951-1971). In details, this indicator is close to unity in the period up to 1951 (values always higher than 0.8), while it quickly goes down in the subsequent decades, stabilizing around 0.6 since 1971. In other words, the phase of more substantial urbanization, observed after World War II, caused a shift away from the normal distribution, with a concentration in cities, mainly Bologna, according to the migration of population from the countryside and

Table 2: Regional values of the statistical indicators of population distribution in Emilia Romagna from 1861 to 2011 [Absolute values in inhabitants per km^2].

	Indicators included in the PCA								Indicators used only in descriptive analysis		
Year	Mean	Coeff. of variation	Normal. range	Median	Skewness	Kurtosis	Harmonic mean	Correlation coefficient (reciprocal)	Range	Median to Mean ratio	Harmonic to Arithmetic Mean ratio
1861	100	0.67	8.1	85	4.4	39.9	72.8	0.000	817	0.85	0.72
1871	108	0.66	7.7	91	4.0	34.0	78.7	0.003	826	0.84	0.73
1881	110	0.66	8.0	94	4.5	40.8	82.0	0.004	880	0.85	0.74
1901	122	0.69	8.7	107	5.4	53.5	91.7	0.013	1068	0.87	0.75
1911	135	0.72	9.3	118	5.9	59.7	99.7	0.006	1248	0.88	0.74
1921	146	0.77	10.2	127	6.4	69.1	106.6	0.004	1486	0.87	0.73
1931	153	0.85	11.3	130	7.0	77.1	107.9	0.006	1738	0.85	0.70
1936	155	0.91	12.7	130	7.8	91.4	107.3	0.002	1968	0.84	0.69
1951	162	1.08	14.7	132	8.0	90.4	104.5	0.008	2392	0.81	0.64
1961	164	1.47	19.2	115	8.0	85.3	88.4	0.013	3140	0.70	0.54
1971	173	1.73	20.0	107	7.0	61.8	71.6	0.018	3473	0.62	0.41
1981	183	1.66	17.7	107	6.1	48.1	66.5	0.006	3254	0.59	0.36
1991	186	1.58	15.4	113	5.5	38.6	62.9	0.004	2867	0.60	0.34

rural areas to the urban centers (Bonifazi and Heins, 2003). After 1981, the emergence of 'the Emilian model', i.e. industrial districts as networks of small manufacturing firms financed by local banks and localized innovation centers fostering the introduction of new technologies in traditional industries (Cooke et al., 1997), gave way to spatially heterogeneous de-concentration processes tying to pre-existing poles of growth and their surroundings.

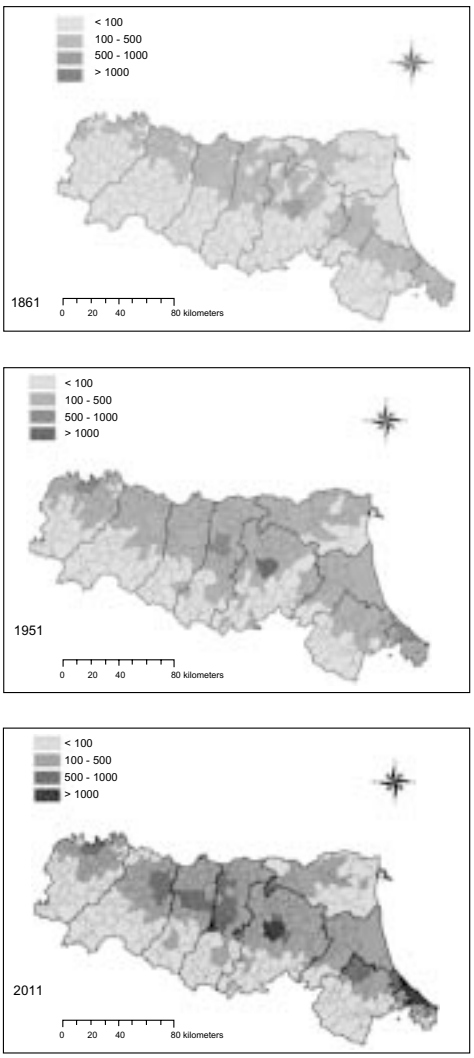

Figure 1: Population density (inhabitants per km^2) in Emilia Romagna by municipality from 1861 (upper panel) to 1951 (medium panel) and 2011 (lower panel)

Figure 1 provides population density maps at the municipal scale in three representative years: 1861, 1951 and 2011. The substantial simplicity of the urban hierarchy was shown by 1861 map, with the main city (Bologna) outstanding for density and the other municipalities placed on a well-distinguishable gradient between those located in the plain with intermediate density and the hilly-mountainous ones with low densities. The year 1951 represented a turning point showing a more complex urban organization, though still anchored to a hierarchy of urban centers with higher functions, mainly provincial capitals. The year 2011 witnesses the evolution towards a moderate polycentrism with the presence of several poles being characterized by intermediate population density. The consolidation of urban areas around the provincial capitals was finally observed along a suburbanization axis typical of the Po Valley.

Principal component loadings and scores are reported in Figure 2. The first three components explain more than 95% of the total variance (with singular contributes amounting, respectively, to 46%, 35% and 14% for the three components). The graph showing the loadings on the first two factors highlights the opposition between indicators of central tendency/dispersion (arithmetic mean, coefficient of variation, normalized range) and shape indicators. Similar features are shown by the loadings on the second and third factor, also highlighting the discrepancy between indicators of dispersion (coefficient of variation) and shape of the statistical distribution (kurtosis, skewness and ratio between harmonic and arithmetic mean), as well as the contrasting pattern of the structural change index compared with central tendency indexes (arithmetic mean and median).

Scores on the first two components show a semi-circular distribution with a turning point around 1961, confirming previous findings. An interesting result comes from the graph of scores on components 2 and 3, providing evidence of different phases in the time points analyzed, with two clusters coinciding with the years 1981-2011 (and partly 1971), on the one side, and the years 1911 to 1951, on the other side. Time points in the early decades of the study (1881, 1901) and in the intermediate stage (1961) were located in the middle.

The analysis shows that the demographic trends in the region, alternating phases of compact and diffused growth, have firstly changed the original spatial configuration according to a mono-centric and concentrated model, followed by slower processes of population re-distribution, with a predominance of leapfrog development along major transport directions (Hall, 2009). According to our data, subtle changes in suburbanization have reverted the polycentric development of industrial districts into scattered expansion on the fringe of major cities (see, for similar findings in the area, Altieri et al., 2014).

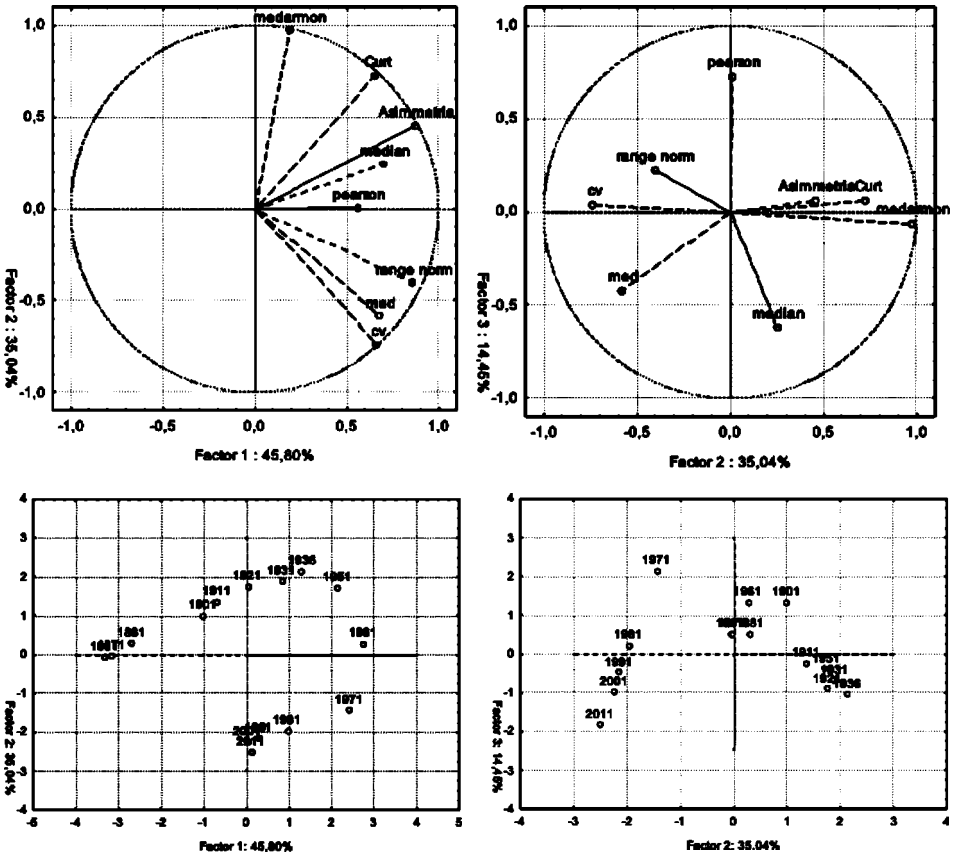

Figure 2: Results of the PCA: Component loadings in the upper panel (component 1 vs 2 on the left, component 2 vs 3 on the right) and component scores in the lower panel (component 1 vs 2 on the left, component 2 vs 3 on the right)

4. CONCLUSIONS

The present study investigates a relevant topic in socioeconomic research and territorial planning. Diffused urbanization, as manifested by the last decades analyzed in this work, is an example of the uneven transformations of a wealthy region requiring an integrated and multi-disciplinary land management.

The spatial analysis of indicators based on multivariate approaches and focusing on the changes in the spatial distribution of the resident population, may represent a useful tool to monitor settlements' diffusion and urban sprawl (McGregor et al., 2006). Such approaches can benefit from an assessment of settlement processes planned at the local and regional levels that takes into account the socioeconomic implications of urban development.

The use of a detailed spatial domain of analysis allows linking urbanization and territorial infrastructure, economic structures and socio-spatial dynamics at the local scale. The procedure developed in this work may be integrated with permanent monitoring schemes at regional and national scale (see Munafò et al., 2010), consistent with aggregated statistical estimates e.g. on a regional scale. Due to complexity in peri-urban systems, innovative land-use policies are needed, that require innovative tools providing an easily updatable information base (Tassinari et al., 2013).

The results of the exploratory analysis showed a rather sharp differentiation between urban and rural districts according to accessibility and population density. A more relevant gradient, however, was identified as tied to the different types of settlements, based on the degree of compactness and densification. This process reflects the transformation of the area surrounding the major urban regions into a non-agricultural, fragmented and discontinuous landscape (Johnson, 2001; Aguilar, 2008; Alberti, 2010).

The pressure resulting from infrastructure and the increased value of peri-urban land, combined with the limited effectiveness of policies of urban containment and re-use of previously built-up spaces, are the possible causes of this latent change. Especially in areas with a marked urban-rural population gap, regional planning should contribute to a rethinking of sub-urbanization as a possible element of competitiveness at the local scale, shifting towards sustainability models - socially cohesive and morphologically compact thanks to efficient measures of urban containment.

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