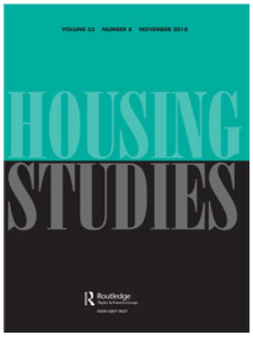

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Crisis-driven changes in construction patterns: evidence from building permits in a Mediterranean city

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ABSTRACT

This study aimed to describe the construction sector's response to the 2007–2008 recession based on the spatial analysis of 10 building activity indicators over a 25-year period (1990–2014) in Athens, Greece. Expansion and recession cycles influenced the average values of four indicators (density of new buildings, average floors per new building, density of enlarged buildings and building permits per inhabitant) without altering their spatial pattern. By contrast, the spatial distribution of six indicators (proportion of small-sized dwellings, average surface area of new buildings, average number of floors in enlarged buildings, average surface area of enlarged buildings, volume ratio of enlarged buildings compared to new buildings and ratio of new building surface area to the absolute population increase) became more heterogeneous during the study period. Local-scale indicators derived from building-permits data provide insights into building cycles, shedding light on the short-term effects of the recent crisis on the construction sector.

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KEYWORDS
Building characteristics; urban region; recession; multivariate analysis; Mediterranean

1. Introduction

The post-war expansion of urban regions in developed countries, and especially in Europe, has been characterized by variable levels of building activity determined by a number of socioeconomic factors at different spatial scales (Costa *et al*., 1991; Coiacetto, 2006; Balta & Eke, 2011). In the long term, urban growth has followed complex and non-linear paths, alternating densification and dispersion waves as a result of different boom and bust phases (Salvati, 2014). As Brown & Liu (2001, p. 1) point out, 'the real estate industry is cyclical by nature (…), the cycles are neither regular nor predictable. Furthermore, the amplitude and frequency of the cycles differ from place to place and from time to time'. Short- and long-term cycles have been identified, with lengths varying by construction sector (e.g. residential, commercial, industrial).

Building cycles have been shown to relate to business cycles, but with specific features that can alter the timing of booms and slumps (You & Zi, 2007). Previous studies have

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identified non-linear fluctuations over time and space in real estate development owing to discrete changes in planning, densification processes or location-specific information (Le Goix, 2005; Mayer & Sommerville, 2000; Weber, 2010; Wu, 2003). The growing literature on comparative European housing policy has also contributed to our understanding of the ways construction and housing patterns are shaped and the interactions between the state, market and civil society are conceptualized in different countries (Fitzpatrick & Stephens, 2014; Guy & Henneberry, 2002; Kemeny & Lowe, 1998; van der Heijden, *et al*., 2011). However, much of this analysis is rooted in the welfare states of western and northern Europe (Arbaci, 2007), with important knowledge gaps for Southern and Eastern European countries.

In line with the increasing debate about the effects of a financial crisis on urban growth patterns (Garcia, 2010; Perez, 2010; Taltavull De La Paz & Gabrielli, 2015), further research is needed to shed light on the role of economic expansions and recessions in shaping the recent building cycles in both developed and emerging regions with relatively homogeneous and singular urban structures, such as Mediterranean Europe. Although this region was amongst the most affected by the 2007–2008 crisis, impacts on building cycles and urban growth have received limited attention, with evidence restricted to specific local contexts, mainly from Spain (Garcia, 2010; Perez, 2010) and Italy (Salvati *et al*., 2016). It has been hypothesized that the reduced building activity observed since the late 2000s has influenced the specific construction market and housing regime. This contrasts with the accelerated building cycle observed in the 1990s and early 2000s (Taltavull de La Paz & Gabrielli, 2015) that often promoted sprawled expansion patterns (Gargiulo Morelli *et al*., 2014). In this sense, A long-term analysis of building cycles that incorporates the most recent crisis period may shed light on recent urban transformations of southern European cities (Salvati & Gargiulo Morelli, 2014), indicating future directions in the development of large metropolitan regions. The present study aimed to identify long-term and short-term responses of the construction industry to economic expansion and recession cycles, reflecting changes in the spatial structure of a large metropolitan region in Mediterranean Europe (Athens, Greece).

The present study aimed to identify long-term and short-term responses of the construction industry to economic expansion and recession cycles, reflecting changes in the spatial structure of a large metropolitan region in Mediterranean Europe (Athens, Greece). The study was based on a diachronic analysis of 10 building activity indicators and 25 contextual indicators evaluating structural and functional aspects of the expansion of Athens. Building activity was analyzed empirically, as a result of distinct cycles in the development of the Athens metropolitan region (Salvati, 2014). Building cycles would be expected to have varying impacts on housing characteristics and the spatial distribution of settlements. The choice of Athens as a paradigmatic example of 'crisis cities' allows the identification of possible urban growth responses to economic expansion and recession (Salvati *et al*., 2016). The relevance of the case selected for analysis goes beyond southern Europe, providing insights into understanding recent urbanization patterns and processes in both developed and emerging countries. Identifying responses of the construction market to economic expansion and recession is key to sustainable planning and management of contemporary cities.

The article is organized as follows: a literature review is proposed in paragraph 1.1 illustrating real estate industry and building cycles. The impact of economic recessions on construction markets was reviewed in paragraph 1.2. Paragraph 1.3 focused on the peculiar construction and housing patterns observed in Mediterranean Europe. Finally, paragraph

1.4 provided an in-depth description of long-term urban dynamics in Athens. Chapter 2 describes the methodologies adopted in this research. Chapter 3 illustrates the most relevant results of our study and Chapter 4 discusses relevance and impact of the empirical evidences proposed here in the light of recent transformations of metropolitan regions in southern Europe. By reframing specific patterns and processes of urban growth during economic expansion and crisis times, the conclusion chapter provides insights into future studies integrating narrative and quantitative approaches and revisiting the main drivers of change in contemporary cities.

1.1. Real estate industry and building cycles

The real estate industry is an important sector of economic activity, with a key role in shaping metropolitan structure and expansion and influencing the overall sustainability of urban forms (Barr & Cohen, 2014). Multiple factors, including loose market regulation (Brown & Liu, 2001), have made the industry not necessarily competitive and, in many instances, highly oligopolistic (Coiacetto, 2006, 2009), producing differential impacts on land development and urban expansion before and after economic recessions (Cho *et al.*, 2015). Analysis of the socioeconomic framing of growth strategies, reflected in construction and housing patterns, coupled with a fine-grained assessment of locally contingent responses of property-holders, could contribute to an in-depth understanding of urban development processes during both expansion and recession periods (Aalbers, 2007; Barras, 2009; Leitner, 1994).

Construction and housing patterns have implications at three main levels: (i) local, because housing markets have place-specific characteristics; (ii) regional, because housing market institutions and housing policies act primarily at the country scale; and (iii) global, because real estate agents, buyers, developers and financiers often transcend national and international boundaries (Aalbers, 2015). In this sense, national and global trends in construction and housing patterns have been routinely linked to local economic and political factors, producing distinct building cycles reflected in more general urban cycles characterized by highly variable levels of building activity (Taltavull de La Paz & Gabrielli, 2015; van der Heijden *et al.*, 2011; Whitehead & Williams, 2011).

1.2. Construction markets and the 2007 economic recession

Impacts of the 2007–2008 financial crisis on the construction market have been regarded as particularly persistent but locally differentiated (Turok & Borel-Saladin, 2016). According to Burke & Hulse (2010), 'the global financial crisis was both precipitated by and had major effects on the performance of housing markets', with impacts reverberating around the world for years (Whitehead & Williams, 2011). However, impacts on construction, housing and mortgage markets differed at the continental scale, although evidence has been collected mainly for the wealthiest countries in the world. In their examination of the underlying trends in place before the financial crisis and the impact of the crisis and government policy responses on the housing and mortgage markets in United Kingdom, Whitehead & Williams (2011, p. 1157) argue that 'the crisis mainly exacerbated already long-established tensions while the current policy solutions have ameliorated, but not fully resolved, these pressures'. Fung & Forrest (2002) explored the dynamics of the Hong Kong housing market and its institutional structure during the Asian Financial Crisis in 1997, focusing on the

interconnections between the housing market and the wider economy and emphasizing the importance of endogenous institutional dynamics in mediating the impact of the financial crisis. In the United States, Shlay (2015, p. 560) reports that the recent housing crisis operated in three ways, as '(i) a dimension of the U.S. system of stratification, (ii) a method for the unfair distribution of resources in metropolitan space, and (iii) a mechanism for the construction of the "other" and as a vehicle for social exclusion.' By contrast, Australia was one of the few Western countries where the housing market was barely affected by the 2007–2008 financial crisis; construction and house price inflation continued on its pre-crisis course (Burke & Hulse, 2010). Taken together, these findings agree with analysis by Barlow (1987), who identified local dimensions of the housing crisis in the new relationship between housing provision and economic restructuring, with greater variety in the responses adopted at the local and individual level.

1.3. Construction patterns in Mediterranean Europe

Research has highlighted the specificity of southern European cities in terms of construction and housing patterns, compared with cities in the rest of Europe (Couch *et al*., 2007; Schneider & Woodcock, 2008; Arbaci & Malheiros, 2010). Settlement informality, family oriented welfare regimes and a lack of housing policies within those welfare regimes have frequently characterized the cities' expansion in this area (Arapoglou & Sayas, 2009; Arbaci, 2007; Malheiros, 2002; Maloutas, 2004). Public housing is restricted to specific locations and social interventions (Delladetsima, 2006), since welfare regimes in European Mediterranean countries mainly focus on education and health, leaving marginal resources for housing (Allen *et al*., 2004; Andreotti *et al*., 2001; Arbaci, 2007; Couch *et al*., 2007). In these countries, low investment in social protection and uncertainty about future pension reform explain why home equity is used as a financial buffer, leading to a high rate of homeownership even amongst low-middle class households (Castles & Ferrera, 1996; Ogg, 2005; Conley & Gifford, 2006). The urban geography of Mediterranean cities reflects a sort of 'residential capitalism' (Arbaci, 2008), with the first ring of peripheral settlements featuring a high rate of homeownership dominated by working class and low-middle class immigrant households. Macro-scale mechanisms of social differentiation or homogenization rooted in redistributive welfare programs and dualist (public/private) housing systems are additionally reinforced by current urban renewal strategies (Arbaci, 2007; Chorianopoulos *et al*., 2010; Balta & Eke, 2011).

1.4. Construction industry and urban growth in a 'crisis city'

Athens, one of the most studied urban areas in southern Europe (e.g. Leontidou, 1990), is considered a paradigmatic example for studying the effects of a persistent economic recession on multiple socioeconomic factors regulating urban growth processes (Chorianopoulos *et al*., 2010; Souliotis, 2013; Salvati, 2014). Athens grew continuously during the twentieth century, as has been observed for a number of southern European cities (Salvati & Gargiulo Morelli, 2014). In the aftermath of World War II, the resident population in Attica grew by 2% per year, totaling 2.0 million people in 1951 (669 inhabitants/km^2). Since the early 1950s, the capital city has contained more than 30% of the Greek population (Salvati, 2014). In 2011, the population reached 3.8 million people (1248 inhabitants/km^2), having grown

by only 0.2% per year between 2001 and 2011 (Figure 1). Construction activities in Athens relied heavily on private capital; the activity of central state institutions was rather marginal and local authorities had limited competencies in planning and funding urban development (Delladetsima, 2006). Private real estate developers and agents have taken advantage of loopholes in planning regulations, continuous revisions of official land value and changes in the building code (Giannakourou, 2005).

Historically, housing was self-financed, mostly by household savings and an informal system of pre-selling and exchange arrangements (Leontidou, 1990). While land allocation was especially de-regulated, the institutional milieu for urban development had long been polarized at the central and local government levels, without any relevant middle tiers (Wassenhoven, 2000). The property transfer tax—formally abolished in 1984—created rigidity in the housing market, limiting geographical mobility, especially of young people. While construction was considered a 'booming' sector in the 1960s, building costs started to rise in the 1970s and mortgage fees have increased rapidly since the 1980s (Couch *et al.*, 2007).

Urban growth regulation has become relatively more homogeneous since the late 1980s (Burgel, 2004). Expansion and stagnation cycles have occurred, with a general trend towards increased dwelling size (Figure 2). Both housing demand driven by natural population increase and the number of newly established informal settlements have decreased moderately (Zitti *et al.*, 2015). A strategic master plan for Attica, the administrative region that encompasses the entire metropolitan area of Athens, was enforced in 1985 and a number of municipalities prepared and approved town plans in the following years (Salvati, 2014). The strategic plan offered a vision for the future development of Athens by securing an urban fringe of high-quality land under environmental protection.

The present study analyzed building activity using data disaggregated at the municipal scale since 1990, characterizing five distinct phases in the development of Athens (Salvati, 2014): (i) deregulated urban expansion driven by internal demand and immigration from the Balkans (1990–1994); (ii) moderate decline in the housing market, real estate speculation and a slow decrease in the interest rate (1995–1999); (iii) a 'building boom' following the announcement of the 2004 Olympic games and expansive, state-driven infrastructure policies (2000–2004); (iv) dispersed urban expansion at the end of the 'building boom' until the early stage of financial crisis, with a rise in homeownership favoured by the decrease in mortgage interest rates on one side and the increase of rents on the other (2005–2009); and (v) crisis of construction market (2010–2014). Each of these phases was expected to have had different effects on building activity, housing characteristics and the spatial distribution of settlements, providing a comprehensive picture of long-term and short-term changes in construction patterns influencing urban morphology and functions (Salvati, 2016).

2. Methods

2.1. Study area

We studied a large part of the Attica administrative region of nearly 3000 km^2, which includes greater Athens. Also known as the Athens 'Large Urban Zone', the area was defined in the Urban Atlas framework as the spatial framework that maximizes the share of residents commuting into the city (European Environment Agency, 2011). The study area consists of 30% flat land, including the plains of greater Athens, Mesogeia, Marathon and Thriasio.

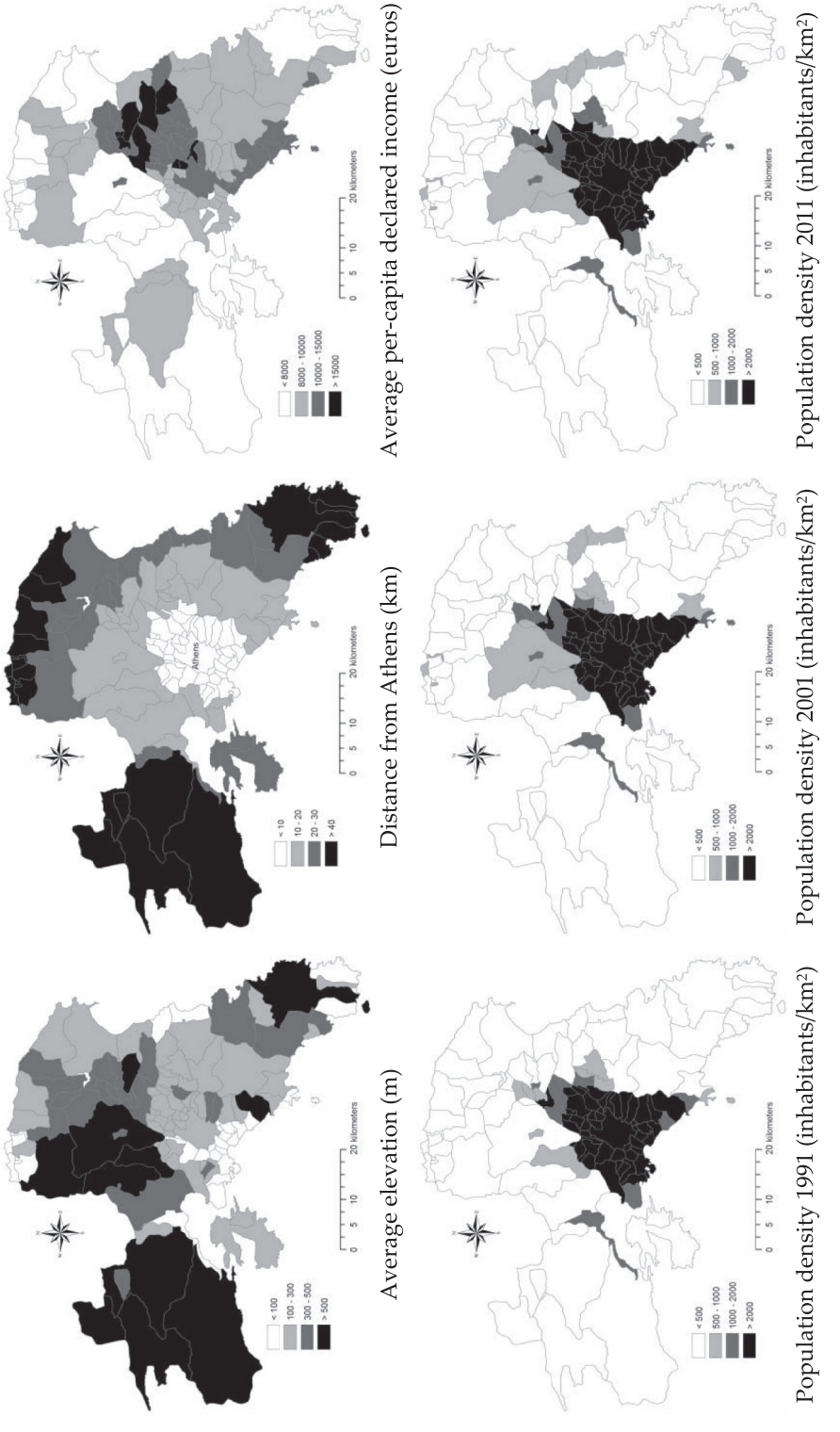

Figure 1. Maps of selected socioeconomic attributes of the study area.

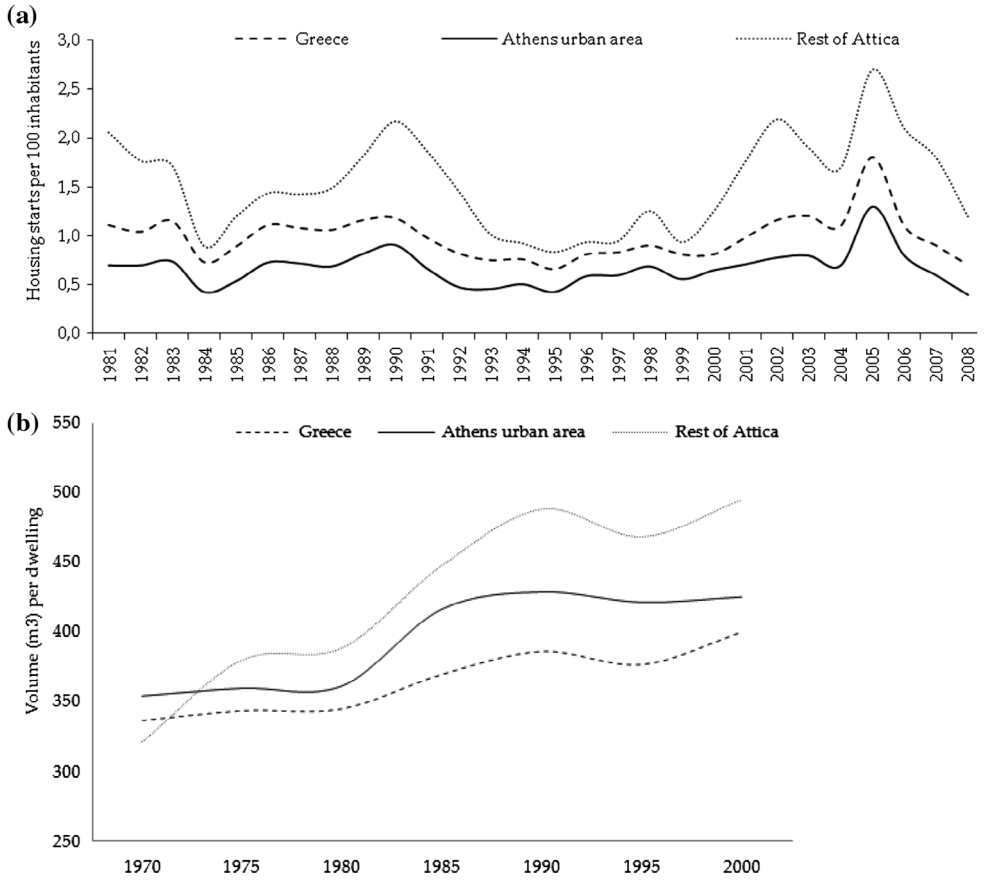

Figure 2. Housing starts per 100 inhabitants (a) and volume (m^3) per dwelling (b) in pre-crisis Greece, by year and district.

Mesogeia and Marathon are mainly specialized in agriculture, while Thriasio was designated in the late 1970s to host industrial settlements. Mountains cover nearly 40% of the study area and include Parnitha (1429 m), Pendeli (1.107 m) and Imitos (1.026 m).

2.2. Data and variables

Data were derived from a survey by the Hellenic Statistical Authority (ELSTAT) in co-operation with local municipalities. Professional engineers in the Town Planning Offices throughout Greece were asked to complete questionnaires on all issued building permits of any kind and value. The study variables included number of new properties and their surface area, volume and estimated building value. Municipal data were available for the last 25 years; for previous years, the geographical scale of the data was less detailed. Disaggregated building permit data can be easily matched with official statistics including national censuses of population or socioeconomic surveys (Polyzos & Minetos, 2013).

The study area was partitioned in 114 municipalities; 58 municipalities administered the greater Athens area (427 km^2), including the cities of Athens and Piraeus. A national law reforming local administrations in Greece (the so-called Kallikratis reform) was enforced in 2011, reducing the number of municipalities in the study area from 114 to fewer than 60. Nonetheless, we analyzed data at the level of 114 municipalities to allow comparability across the entire study period.

2.3. Indicators of building activity

We calculated 10 indicators derived from primary data at the municipal scale, collected on behalf of the ELSTAT building activity survey, referring to the building permits issued in each of the five time intervals studied (1990–1994, 1995–1999, 2000–2004, 2005–2009, 2010–2014): (i) density of new buildings (per km^2), (ii) average number of floors per new building, (iii) average surface area per new building (m^2), (iv) density of enlarged buildings (per km^2), (v) average number of enlarged floors per building, (vi) average enlarged surface area per building (m^2), (vii) ratio of enlarged building volume (m^3) to newly built volume (m^3), (viii) share of houses with 1 or 2 rooms in the newly built housing stock (%), (ix) ratio of newly built surface area (m^2) to the absolute population increase (inhabitants) and (x) number of new building permits per inhabitant. Primary variables were selected according to Hee Goo (2014), Gargiulo Morelli *et al.* (2014) and Salvati *et al.* (2016) and reflect both structural and functional aspects of urban expansion at the local scale. These indicators provide a comprehensive picture of building activity in the study area (Salvati, 2016), identifying relevant dimensions of analysis and correlating them with key variables in assessing urban expansion, such as population growth and potential land availability. Resident population and land surface for each municipality of the study area were derived from data collected by ELSTAT on behalf of the national census of population and households. The spatial distribution of each indicator was illustrated over time using maps provided by ELSTAT.

2.4. Contextual indicators

A total of 25 socioeconomic and territorial indicators were calculated at the municipal scale with the aim of describing four structural and functional dimensions of urban expansion: (i) population, (ii) land-use, (iii) urban functions and (iv) topography and territory; these dimensions and their respective indicators are shown in Table 1. A high-resolution map developed as part of the Urban Atlas initiative by the European Environment Agency (2011) was used to calculate the ratio of compact to dispersed settlements. Using the ArcGIS 9.3 package (ESRI Inc, Redwoods, USA), the geometric distance was calculated between each municipality and the centre of four towns: Athens, Piraeus, Maroussi—an urban municipality hosting the new Olympic Stadium—and Markopoulo Mesogeias—the centre of the rapidly expanding Mesogeia district that includes the Athens international airport. Indicators were selected as representative of the main urbanization processes observed in the study area, based on previous work by Salvati & Serra (2016).

Table 1. List of the contextual variables used in the present study.

Acronym	Variable	Measurement unit	Source
Population			
d	Population density	inhabitants/km^2	Population census
g	Annual population growth rate	%	|
s	Sparse population	% of total population	|
Com	Compact vs. dispersed settlements	% surface ratio	European Environment Agency
		Land-use	
a	Cropland	% of total municipal area	
f	Forests	% of total municipal area	|
Eve	Pielou's index of land-use diversity	Score (0–1)	|
p	Protected land	Dummy (0: non-protected; 1: protected)	Territorial statistics
o	Municipal master plan enforced in law	Dummy (0: not yet; 1: yes)	Town Planning Office
c	Self-contained buildings	% of total buildings	Building census
Urban functions			
r	Residential buildings	% of total buildings	Building census
i	Industrial buildings	% of total buildings	|
t	Hotel-use buildings	% of total buildings	|
e	Service/commerce buildings	% of total buildings	|
m	Multiple-use buildings	% of total buildings	|
u	Diversity in building usage	No of building uses on the municipal area	|
Inc	Average declared income	Euros per-capita	Greek Ministry of Finance
Topography and territory			
Ele	Mean elevation	M	Population census
Sea	Proximity to the sea shore	Dummy (0: internal; 1: coastal)	Territorial statistics
dAth	Distance from Athens	km	|
dPir	Distance from Piraeus	km	|
dMar	Distance from Maroussi	km	|
dMak	Distance from Markopoulo M.	km	|
Sqi	Soil Quality Index	Score (0–1)	European Environment Agency
Cqi	Climate Quality Index	Score (0–1)	|

2.5. Statistical analysis

The collected data were analyzed using a three-part data mining framework: (i) descriptive statistics, (ii) inferential approaches and (iii) multivariate analysis. Integrated statistical techniques contribute to understanding local-scale, spatio-temporal changes in building activity and to identifying the most relevant characteristics of the underlying socioeconomic context (Salvati & Serra, 2016). Although these statistical techniques help to identify latent factors reflecting the complexity of socioeconomic local systems during economic expansion and recession (Gargiulo Morelli *et al.*, 2014), there are limitations to this approach because correlation and similarity patterns do not necessarily imply causation (Zitti *et al.*, 2015). Quantitative methods share a common weakness when applied to elicit information in order to achieve a holistic understanding of multi-faceted, not directly observable phenomena. However, the suggestions about housing cycles' drivers coming from the results of our analysis could be helpful in informing interpretation based on qualitative approaches such as focus groups, Delphi panels and in-depth interviews to privileged observers, stakeholders or key experts.

2.5.1. Descriptive statistics

For each indicator, median values were calculated for the five 5-year intervals of the study period; changes over time in the spatial distribution of selected indicators in the study area were illustrated by mapping. We selected municipalities as the minimum spatial unit of this study. In Greece, municipalities have a role in planning land-use, building volume and settlement size (Chorianopoulos *et al.*, 2010). While representing arbitrary units, administrative boundaries have been widely used in economic and socio-demographic analysis (e.g. Garcia & Riera, 2003; Gargiulo Morelli *et al.*, 2014; Salvati, 2016).

2.5.2. Inferential statistics

A non-parametric inferential approach was applied, with the aim to test changes over time in the statistical distribution and in the spatial configuration of each indicator. Significant differences in the median value of each indicator over the whole time period (1990–2014, divided into 5-year intervals) were tested using the Friedman one-way analysis of variance with $\alpha < 0.05$ confidence level. Changes in the spatial configuration of each indicator over the 25-year study period were studied by computing the Kendall concordance coefficient ranging from −1 (discordance in the spatial data series) to 1 (concordance in the spatial data series). The non-parametric Kendall test was run to identify significant ($\alpha < 0.05$) coefficients under the null hypothesis of uncorrelated variables (coefficient = 0). Kendall coefficients close to 1 indicate a concordant spatial regime over time, while values close to 0 indicate a changing spatial configuration of the variable of interest.

A similar inferential approach was used with the aim to compare the value of every indicator for each pair of consecutive time intervals (e.g. 1990–1994 *vs.* 1995–1999, … , 2005–2009 *vs.* 2010–2014). Wilcoxon tests (z-statistic) were run to test changes in the median value of each indicator for the given time interval. Spearman rank coefficients were computed to identify variations in the spatial regime of each indicator for the same time interval. Significance was tested at $p < 0.05$ after Bonferroni correction for multiple comparisons.

2.5.3. Multivariate statistics

A multiway factor analysis (MFA) was run with the aim to obtain a comprehensive overview of spatio-temporal patterns of building activity based on the 10 indicators studied, measured for each of the five time intervals for every municipality in the study area. Considered a generalization of principal component analysis (Escofier & Pages, 1994), the MFA identifies complex structures in higher order datasets (Coppi & Bolasco, 1988), allowing for an indirect measure of the impact caused by external drivers (Kroonenberg, 2008). The analysis associates variables with similar spatio-temporal patterns on a few relevant (eigenvalue > 1) components using loadings that range from −1 (negative correlation) to 1 (positive correlation). Component scores were mapped, allowing identification of clusters of municipalities characterized by a similar spatio-temporal pattern in building activity. The correlation between the extracted MFA components and the 25 contextual variables was studied using pair-wise non-parametric Spearman rank coefficients testing at $p < 0.05$ after Bonferroni's correction for multiple comparisons.

3. Results

3.1. Descriptive statistics

Trends over time for the 10 indicators of interest in the present study are reported in Table 2. The density of new buildings remained high over two decades, 1990–2009, with a peak in the pre-Olympic period (2000–2004) and a drastic decline afterwards. The average number of floors per new building increased before the crisis, reaching a peak in the 2005–2009 period (2.5 floors) and decreasing moderately in recent years (2.3 floors). The average surface area per new building followed a similar pattern, decreasing by nearly 100 m^2 per building in the crisis period. The highest number of building enlargements was observed in the first time interval, decreasing slightly afterwards. However, both the number of new floors in enlarged buildings and the average surface area of enlargements increased moderately over time, reaching a peak in 2005–2009, in line with what was observed for new buildings. The ratio of enlarged building volume to new building volume remained relatively stable (around 20%) along the study period, then doubled in 2010–2014. The percentage of small dwellings was stable (around 20%) up to 2000–2004, increasing rapidly thereafter. The ratio of new building surface area to the absolute population increase remained almost stable (around 80 m^2) up to 2000–2004, doubled during 2005–2009 and then declined to 22 m^2 in 2010–2014. The ratio of building permits to resident population was quite stable (around 2 permits per 100 inhabitants), then declined 10-fold during the crisis. Taken together, descriptive statistics illustrate the impact of the 2007–2008 crisis on building activity with respect to previous expansion and recession cycles.

Figure 3 illustrates the main changes in the spatial distribution of selected building activity indicators, identifying different spatial configurations often associated to the urban gradient. The density of new buildings shows a typical mono-centric pattern, decreasing in intensity with the distance from the inner city of Athens. This pattern was modified slightly over time, with a more scattered distribution during the Olympic decade (2000–2009) as a result of sprawled urban expansion into fringe land. At the beginning of the study period, the average surface area of new buildings increased from west (poor neighbourhoods) to east (affluent neighbourhoods), following the socioeconomic polarization observed in greater Athens since the 1980s (Leontidou, 1990). Both in times of expansion and of recession, the highest values for this indicator were observed in peripheral areas.

The ratio of enlarged building volume to new building volume remained relatively scattered throughout the space, with moderately higher values observed on fringe land. The percentage of small dwellings in new housing construction was higher in the urban area during 1990–1994 and 2005–2009, but showed a significant increase in suburban areas during 1995–1999. The ratio of new building surface area to absolute population increase maintained a scattered spatial pattern up to the early 2000s, increasing in peripheral areas in the most recent decade, indicating persistent suburban growth during both economic expansion and crisis. The ratio of the absolute number of building permits to resident population showed a stable distribution, increasing along the west-east gradient.

3.2. Inferential statistics

Based on a non-parametric inferential approach, the indicators with the most significant changes (Friedman test) in the median value over the study period were density of new

Table 2. Indicators of building activity in the study area by time interval.

Time interval	Density of new buildings	Average number of floors per new building	Average surface area of new buildings	Density of enlarged buildings	Average number of enlarged floors per building	Average enlarged surface per building	Volume ratio of enlarged buildings compared to new buildings	Share of houses with 1 or 2 rooms in the newly built-up house stock	Ratio of newly built-up surface to the absolute population increase	Number of new building permits per inhabitant
1990–1994	21.29	2.13	421.55	14.79	1.08	161.62	0.22	0.21	80.02	0.022
1995–1999	19.52	2.18	486.20	11.22	1.11	168.69	0.24	0.17	61.60	0.015
2000–2004	30.20	2.35	495.46	11.64	1.17	203.29	0.17	0.21	95.49	0.016
2005–2009	29.40	2.48	507.93	10.25	1.34	238.63	0.20	0.28	152.16	0.015
2010–2014	4.30	2.29	403.48	3.56	1.20	209.54	0.43	0.26	22.25	0.002

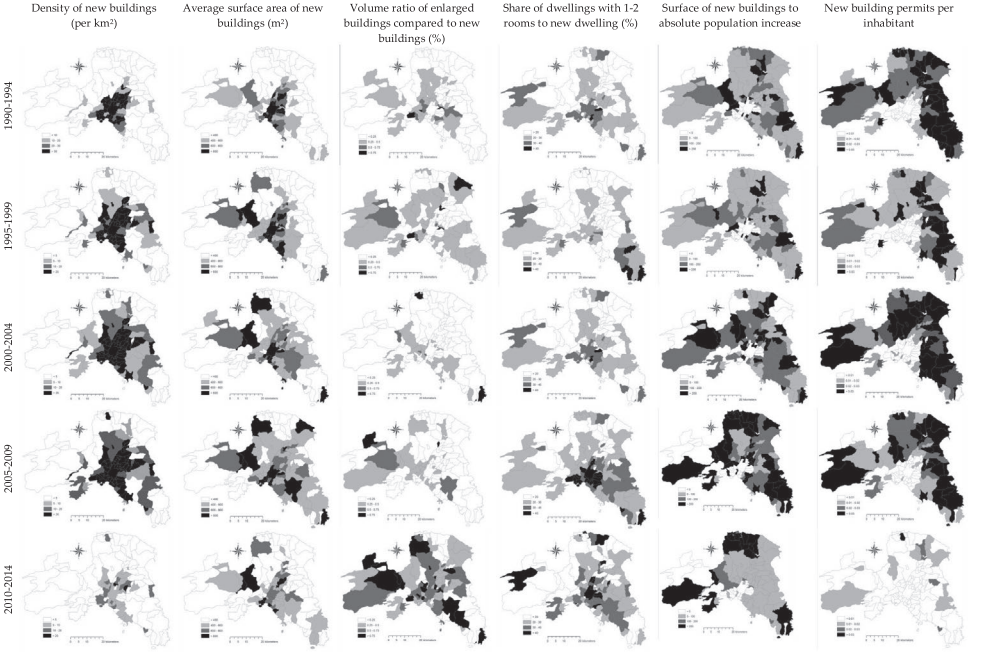

Figure 3. Trends in building activity for each municipality of the study area by time interval.

buildings, average number of floors per new building, density of enlarged buildings and building permits per inhabitant (Table 3). Indicators with the lowest concordance coefficient (indicating a significant change in the spatial regime) were average surface area of new buildings, average floors and surface area of enlarged buildings, ratio of enlarged-to-new building volume, percentage of small-size dwellings and ratio of new building surface area to the absolute population increase. Taken together, four indicators showed a stable spatial configuration, with relevant variations in the median value over time, and six indicators showed differences in spatial configuration, with moderate or slight changes in median value.

A similar inferential approach was used to compare the variables' distribution over each pair of consecutive 5-year intervals. According to Wilcoxon tests, the average number of floors per new building is the only variable showing significant changes over the four decades studied. Seven of the 20 indicators differed significantly in distribution across the first (1990–1999) and second (1995–2004) decades, five in the third decade (2000–2009) and seven in the most recent decade (2005–2014). Indicators assessing the main characteristics of new buildings were more variable in the first and the last decade, in contrast with what was observed for the indicators quantifying building enlargements. Concordance analysis (Figure 4) identifies a stable spatial regime for the density of both new and enlarged

Table 3. Non-parametric analysis of variance testing for differences in the statistical distribution of each indicator over the whole time period (Friedman) or between selected time intervals (Wilcoxon).

	Friedman ANOVA		Wilcoxon test (z-statistic)			
Variable	Test statistic	Concordance coefficient	1990–1994/ 1995–1999	1995–1999/ 2000–2004	2000–2004/ 2005–2009	2005–2009/ 2010–2014
Density of new buildings	276.7**	0.60**	6.1**	7.1**	3.8	9.3**
Avg. number of floors per new building	172.3**	0.37*	5.6*	5.4*	6.3**	8.0**
Average surface area of new buildings	78.3*	0.16	4.7*	0.3	2.9	7.0**
Density of enlarged buildings	217.3**	0.47**	6.8**	3.7	4.1*	9.3**
Avg. number of enlarged floors per buil.	124.7**	0.26	1.9	4.6*	5.9*	2.9
Average enlarged surface per building	142.7**	0.30	2.3	5.2*	4.0*	2.3
Enlarged-to-new buildings volume	135.5**	0.29	0.9	5.3*	2.0	8.0**
Share houses (1–2 rooms) in new houses	160.6**	0.32	4.9*	4.9*	7.3**	2.7
Newly built-up surface to pop. increase	68.2*	0.14	5.0*	1.1	3.4	6.1**
New building permits per inhabitant	256.7**	0.55**	7.2**	4.0*	3.5	9.3**

*Indicate significance at $p < 0.05$ after Bonferroni's correction for multiple comparisons.;
**Indicate significance at $p < 0.001$ after Bonferroni's correction for multiple comparisons.

buildings, the average number of floors per building and the number of building permits per inhabitant over the entire study period. Average number of floors per enlarged building, average surface area of enlarged buildings and the ratio of enlarged-to-new building volume showed relatively low concordance coefficients over time. The percentage of small-size dwellings and the ratio of new building surface area to population increase showed the opposite spatial pattern, decreasing and increasing in concordance over time, respectively.

3.3. Multivariate statistics

The MFA extracted four components explaining 57.5% of the total variance. Component 1 (27.4%) illustrates the mono-centric structure prevailing in Athens, being associated to 5 indicators in 1990–1994 and to 3 indicators in 2010–2014. Density of both new buildings and enlarged buildings, and the average number of floors per building showed positive and stable (or increasing) loadings to component 1 over the whole study period (Table 4). A positive loading was assigned to the average number of floors per enlarged building for the time intervals 1990–1994 and 1995–1999. The percentage of small-size dwellings was positively associated to component 1 during expansion cycles only (1990–1994, 2000–2004, 2005–2009). Finally, the number of building permits per inhabitant was negatively associated to component 1 in the 'building boom' phase (2000–2004). Figure 5 illustrates the spatial distribution of MFA scores at the municipal level in the study area.

Component 1 scores decreased along the urban-rural gradient during the whole time period. The highest negative scores were observed in the northern and southeastern fringes of Athens in 1990–1994 and across the whole metropolitan region in 2010–2014. Scores were correlated to a number of contextual indicators showing stable Spearman coefficients over time. Negative correlations were found for mean elevation, per-capita built-up area, percentages of residential buildings, population living in sparse settlements, cropland and forest areas, and the distances from Athens, Piraeus and Maroussi. Population growth rate was negatively associated to component 1 except for the most recent time interval. This result indicates the shift towards a more balanced demographic pattern in the area. Positive

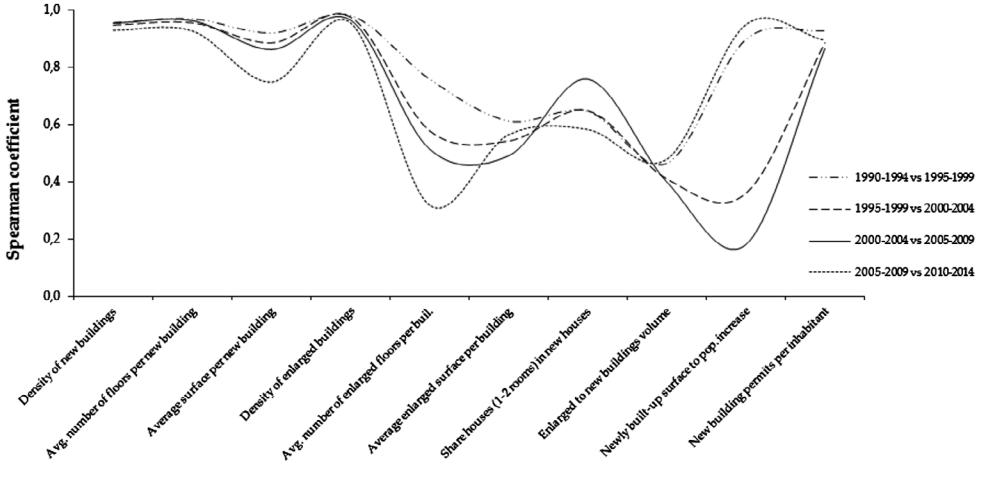

Figure 4. Non-parametric Spearman concordance analysis by indicator and time interval.

Table 4. Significant (> |0.5|) MFA component loadings*.

	1990–1994				1995–1999				2000–2004				2005–2009				2010–2014			
Variable	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Density of new buildings	0.69				0.73				0.69				0.73				0.72	−0.57		
Avg. number of floors per new building	0.78				0.82				0.82				0.84				0.81			
Average surface area of new buildings		0.57				0.55				0.64				0.57				0.55		
Density of enlarged buildings	0.77				0.77				0.82				0.76				0.81			
Avg. number of enlarged floors per buil.	0.73				0.60															
Average enlarged surface per building			0.56				0.51				0.50				0.54					
Share (1–2 rooms) houses in new houses	0.52						−0.53		0.52				0.69							
Newly built-up surface to pop. increase																0.50				0.63
New building permits per inhabitant									−0.52							0.61				0.63

*Volume ratio of enlarged buildings compared to new buildings was not correlated to any MFA component.

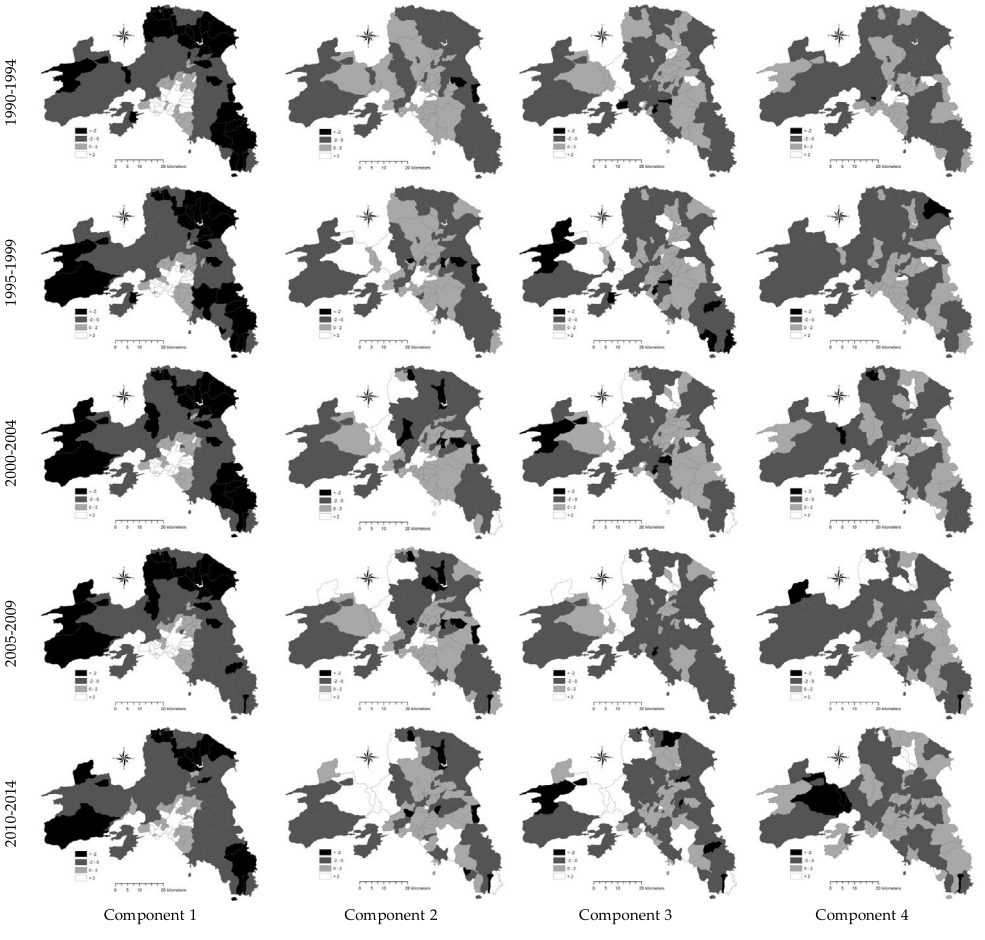

Figure 5. The spatial distribution of MFA scores by component and time interval.

correlations were found with population density, ratio of compact-to-dispersed settlements, diversity in land use and building use, and percentages of service and commercial buildings and of multiple-use buildings. The enforcement of a municipal master plan also received a highly positive loading to component 1 (see Table 5).

Component 2 (13.5%) was associated positively with the average surface area of new buildings over the entire study period. A negative loading was assigned to the density of new buildings for 2010–2014. Component 2 scores showed a moderate east-west gradient (particularly evident in the decade 1990–1999), and were correlated positively with average per-capita declared income, percentages of multiple-use buildings and of service/commercial buildings, population density and diversity in land-use. Residential buildings, percentages of sparse population and cropland, and distances from Athens, Piraeus and Maroussi were correlated negatively with component 2.

Table 5. Pair-wise Spearman non-parametric correlation between MFA components and contextual variables (only significant coefficients at $p < 0.05$ after Bonferroni's correction for multiple comparisons were reported)*

	Time interval	Population density	Annual population growth rate	Sparse population	Compact vs. dispersed settlements	Cropland	Forests	Municipal master plan enforced in law	Pielou's index of land-use diversity	Residential buildings	Service/commercial buildings	Multiple-use buildings	Diversity in building usage	Average per-capita declared income	Mean Elevation	Distance from Athens	Distance from Piraeus	Distance from Maroussi	Distance from Markopoulo
Component 1	1990–1994	0.91	−0.56	−0.72	0.71	−0.79	−0.42	0.35	0.60	−0.35	0.49	0.75	0.74		−0.38	−0.86	−0.83	−0.57	
	1995–1999	0.93	−0.55	−0.70	0.72	−0.78	−0.49	0.40	0.62	−0.34	0.52	0.73	0.77		−0.42	−0.84	−0.82	−0.54	
	2000–2004	0.93	−0.49	−0.70	0.72	−0.82	−0.39	0.54	0.60	−0.48	0.44	0.76	0.80		−0.48	−0.82	−0.82	−0.51	
	2005–2009	0.92	−0.52	−0.64	0.77	−0.80	−0.38	0.53	0.58	−0.47	0.46	0.77	0.77		−0.50	−0.83	−0.82	−0.49	
	2010–2014	0.92		−0.71	0.68	−0.82	−0.49	0.41	0.66	−0.46	0.48	0.61	0.81		−0.40	−0.87	−0.81	−0.63	
Component 2	1990–1994	0.45		−0.44		−0.48			0.37	−0.38	0.35	0.38		0.39		−0.53	−0.48	−0.41	
	1995–1999					−0.33				−0.36						−0.36			
	2000–2004									−0.37									
	2005–2009									−0.34									
	2010–2014																		
Component 3	1990–1994													0.47				−0.37	
	1995–1999													0.44				−0.47	
	2000–2004													0.34					
	2005–2009																		
	2010–2014																		
Component 4	1990–1994	0.33				−0.33					0.36	0.35							−0.34
	1995–1999																		−0.42
	2000–2004																		
	2005–2009																		
	2010–2014																		

*The following variables were not correlated to any MFA component: protected land, self-contained buildings, industrial buildings, hotel-use buildings, proximity to the sea shore, soil quality index, climate quality index.

Component 3 (9.4%) was associated positively with the average surface area of enlarged buildings for all time intervals except 2010–2014. The percentage of small-size dwellings received a negative loading during the 2000–2004 'building boom'. High positive scores were concentrated in the western fringe of Athens. Component scores were correlated positively with average per-capita declared income and negatively with the distance from Maroussi, the municipality hosting the new Olympic stadium.

Positive loadings to component 4 (7.1%) were assigned to the ratio of new building surface area to absolute population increase and to the number of building permits released in the last decade. Component 4 score mapping illustrated a peri-urban spatial pattern consolidating over time, with higher scores observed in western and southeastern fringe municipalities. During the first decade studied, component scores were correlated negatively with the distance from Markopoulo Mesogeias and the percentages of residential buildings and cropland. Positive correlations with the percentages of service/commercial buildings and multiple-usage buildings were observed.

4. Discussion

Recession has been considered an opportunity for sustainable urban development (Florida, 2011) because it may drive urban expansion towards land-saving and functional structures that are spatially balanced (Salvati *et al.*, 2016). The present study attempted to contribute empirical verification of this line of thinking by characterizing areas where the housing construction and market profile diverged before and after the 2007–2008 financial crisis. The indicators selected in this study provide a comprehensive assessment of the distinct dimensions of building activity and their implications for urban structure in a socioeconomic context representative of demographic changes, informal housing patterns and deregulated urban growth typical of emergent countries or economically disadvantaged regions in developed countries (e.g. Polyzos & Minetos, 2013).

Discontinuous and dispersed settlements have resulted from specific patterns of urban growth consolidated during periods of economic expansion (Salvati *et al.*, 2016). Pre-crisis building activity—driven by prospects of prosperity and by a desire for space and for neighbourhoods without crime, noise and pollution—prompted the diffusion of semi-detached and large, isolated dwellings in peri-urban areas (Diappi, 2013). The 2007 recession enlarged the dichotomy between peripheral rural areas and central cities. The spatio-temporal trends observed in the indicators that we analyzed reflect a marked differentiation between urban and peri-urban municipalities in building activity and in the underlying socioeconomic context. Urban areas appeared less affected by the 2007–2008 crisis, while peri-urban areas responded faster to economic expansion. Fringe municipalities showed intermediate (and highly variable) levels of building activity, indicating a major diversification in construction patterns at the local scale; this diversification increased during the most recent crisis period.

Based on this perspective, our approach allows differentiating variables that reflect changes impacting the spatial organization of a given district from those variables indicating changes that alter the average socioeconomic profile of the district, without impact on the urban structure. In Athens, the spatial distribution of four indicators (density of new buildings, average floors per new building, density of enlarged buildings and number of building permits per inhabitant) was relatively stable over both expansion and recession cycles, with only moderate variations in their mean values. In contrast, the spatial distribution of the remaining six indicators (average surface area of new buildings, average floors

and average surface area of enlarged buildings, ratio of enlarged to new building volume, proportion of small-sized dwellings and ratio of new building surface area to the absolute population increase) differed markedly between expansion and recession cycles, becoming spatially heterogeneous after the 2007–2008 crisis.

Building cycles in Athens were found rather different from what has been observed in similar Mediterranean socioeconomic contexts, such as Spain and Italy, where property markets showed a sustained period of growth from the 1990s until 2007–2008, when both markets fell into decline (more rapidly in Spain) due to the worldwide economic crisis (Taltavull de La Paz & Gabrielli, 2015). These findings partly contrast with empirical evidence from earlier studies (Allen *et al*., 2004; Burgel, 2004; Leontidou, 1990). Before the beginning of the financial crisis, homogeneous conditions for urban expansion were thought to exist throughout the Mediterranean region (Chorianopoulos *et al*., 2010; Delladetsima, 2006; Salvati & Serra, 2016). However, it was more recently demonstrated how Spain, Italy and Greece reacted to the crisis differently in their real estate markets, housing prices, building construction and planning regulations (Garcia, 2010; Perez, 2010; van der Heijden *et al*., 2011).

For example, the negative impact of the credit crunch on housing development was stronger in Spain than in Italy and Greece (Díaz-Pacheco & García-Palomares, 2014). The extraordinary growth in Spain's housing construction during the 2000s explains the observed differences in town-planning models and the defects in oversight mechanisms for municipal development (Costa *et al*., 1991; Garcia & Riera, 2003; Gargiulo Morelli *et al*., 2014); indeed, town planning, amongst other factors, has become a serious source of political corruption in Spain (Jiménez, 2009). In contrast, the building boom in Italy was quite moderate, especially in the north, and dispersed urbanization was the dominant model for expansion (Salvati & Gargiulo Morelli, 2014). Per-capita land consumption was particularly high because of the stable demographics and sprawled development (Salvati *et al*., 2016). In between these modalities, recent building cycles in Greece, and especially Athens, were characterized by fluctuations in construction activity and spatial heterogeneity in urban form and functions (Gargiulo Morelli *et al*., 2014). These results corroborate the idea of distinct development paths for contemporary Mediterranean cities, based on place-specific factors that influenced the housing market and were reflected in different building cycles (Carlucci *et al*., 2017).

Taken together, these and much earlier results (Barras, 2009; Castles & Ferrera, 1996; Mayer & Somerville, 2000) point out the intimate link between building cycles and changes in the urban form and could contribute to the design of local developmental policies that support the construction industry and housing market, while also promoting more sustainable urban forms (Pili *et al*., 2017). Recession shaped major changes in socio-spatial urban structures and economic polarization following the re-urbanization of inner cities, and also contributed to a moderate shift towards more compact urban growth as housing prices fell sharply. To improve metropolitan sustainability, these (re)densification processes should be supported by local and regional policies of urban containment (Salvati & Gargiulo Morelli, 2014). Construction market incentives (e.g. tax reduction measures) should be specifically oriented towards the promotion of brownfield building, incorporating mechanisms that discourage urban expansion into greenfields. Subsidies can be specifically directed to urban regeneration and recovery of derelict and abandoned areas (e.g. industrial settlements in central and semi-peripheral

districts). Urban voids and degraded (often informal) low-density settlements in sub-urban areas can be converted to denser residential districts through selective planning actions (Gargiulo Morelli *et al*., 2014). Small-scale transformations in urban cores can be promoted by specific public investment and tighter control on land prices to encourage spatially balanced urban development. Finally, local authorities should assure a truly effective application of official land zoning, avoiding proliferation of informal housing in marginal areas ill-suited for housing sites (Chorianopoulos *et al*., 2010).

In this sense, recent data from Athens indicate a clear preference of new enterprises to settle in previously planned urban areas, indirectly promoting settlement densification and social re-balancing (Chorianopoulos *et al*., 2014). In contrast with the informal settlements typically observed in the 1970s and 1980s, this self-contained mode of urban growth may be interpreted as an endogenous response to various socioeconomic processes and reflects the crisis of imbalanced city models (Garcia, 2010). By stimulating a 'great reset' in urban planning and regional development policies, as evoked by Florida (2011), the 2007 crisis appears a unique opportunity to promote a more sustainable path of city expansion in a context of austerity urbanism (Salvati *et al*., 2016).

5. Conclusions

The analysis of spatio-temporal changes in building permit data is a promising tool from both the research and policy perspectives that can help to interpret the long-term expansion of large cities, providing evidence on recent changes in urban morphology and socioeconomic functions likely driven by economic crisis. Our approach identified indicators of building activity that show significant changes in spatial distribution and intensity. The indicators also reveal long-term spatio-temporal patterns of building activity as a result of distinct phases of economic expansion and recession. In this line of thinking, municipalities were a meaningful unit for the analysis of building characteristics and settlement dispersion.

Understanding complex metropolitan systems' dynamics increasingly requires methodologies integrating exploratory data analysis with (non-parametric) inferential approaches to cross-scalar, non-linear relations between urban form and economic functions. Our study specifically contributes to this deserving issue. Future research should be also devoted to integrate exploratory approaches oriented to the analysis of complex urban systems with more traditional econometric approaches that interpret metropolitan growth modelling causal interactions between key socioeconomic variables. Moreover, although quantitative variables may provide an articulated economic profile of local communities, further studies are needed to identify and improve the collection of both quantitative and qualitative indicators related to differential patterns of urban development during economic expansion and stagnation alike. Future research is finally required to explore the latent relationship between local development policies and building cycles within the framework of recent sprawled expansion surrounding large cities.

Disclosure statement

No potential conflict of interest was reported by the authors.

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