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Local development, metropolitan sustainability and the urbanization-suburbanization nexus in the Mediterranean region: A quantitative exercise

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ABSTRACT

The present study investigates the influence of economic growth and socio-demographic change on long-term urbanization and suburbanization processes in a divided region of Southern Europe (Athens, Greece). A two-block Partial Least Squares (tPLS) analysis decomposed metropolitan growth into distinctive processes of local development in 'central' and 'peripheral' areas considering changes over time (1966–2008) in 14 indicators representative of multifaceted territorial dynamics in the Mediterranean space. By quantifying the bi-directional (spatio-temporal) propagation of socioeconomic impulses, the empirical results of tPLS have delineated substantial differences in the development path of inner cities and suburbs, fueling spatial divides in social conditions and increasingly heterogeneous processes of regional development. While inner cities experienced population growth and settlement densification, peripheral areas underwent rapid suburbanization with spatial concentration of economic functions and a generalized settlement dispersion. Providing further insights in the analysis of the differential mechanisms of metropolitan development in Western Europe, results of this study confirm the specificity of urbanization and suburbanization processes at the base of the increased polarization in central and peripheral areas typical of Mediterranean countries.

1. Introduction

With social changes, contemporary economic systems underwent intrinsic fluctuations that influence urban cycles (Cheshire, 1995; Fratesi & Rodríguez-Pose, 2016; Glaeser et al., 2006; Nickayin et al., 2022), orienting sometimes metropolitan regions toward new development paths (Dahan & Tsiddon, 1998; Black & Henderson, 1999; Haase et al., 2010). These paths depend – more intensively than in the past – on sequential waves of economic expansion and shrinkage (Fernandez & Hartt, 2021; Hale & Moberg, 2003; Salvati, 2022). Market dynamics, property values, housing policies, and the background socio-demographic context, assume a distinctive role in metropolitan cycles, justifying a comprehensive analysis of building activity and settlement characteristics at local scales (Cervellati & Sunde, 2011; Felsenstein, 2002; Harrison & Heley, 2015; Kashnitsky et al., 2021).

According to the theory of City Life Cycle (CLC), urbanization and suburbanization were regarded as sequential stages of metropolitan development (Berry, 1980; Duvernoy et al., 2018; Klaassen et al., 1981). At the same time, empirical tests of CLC theory in contemporary cities were basically run considering variations over time in individual (target) variables at the base of metropolitan growth (Heider & Siedentop, 2020; Kabisch & Haase, 2011; Morelli et al., 2014) – and especially population dynamics in inner cities and suburbs (De Vidovich & Scolari, 2022; Delmelle et al., 2021; Erkip, 2000; Gordon & Cox, 2012). The univariate analysis of a single attribute of urban expansion, such as population growth, provided partial – and sometimes biased – evidence to CLC assumptions (e.g. Silverman, 2020). This simplified approach is grounded on a spatio-temporal decomposition of population growth rates, comparing demographic trends in different places along the metropolitan gradient (Morya & Ram, 2020). In this perspective, the

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role of a given stage of the cycle (e.g. urbanization) shaping the subsequent stage (e.g. suburbanization), has been frequently demised (Cuberes & González-Val, 2017; Sánchez-Vidal et al., 2014; Sheng et al., 2014).

Moreover, the inherent specificity of country, regional, and local contexts undergoing urbanization and suburbanization waves was poorly investigated and the possible feedbacks and spillovers between the two processes were often identified in a partial and fragmented way (with few exceptions, e.g. Giuliano et al., 2019; Shen & Wu, 2020; Bailey, 2021). Although it was often recognized as a key factor of regional development (Salvati et al., 2018), the intimate (bidirectional) linkage between urban and suburban growth needs further scrutiny in a long-run perspective (Nam et al., 2012), e.g. quantifying both direct and indirect impulses of urbanization toward suburban growth (e.g. Lestegàs, 2019).

With this perspective in mind, econometric models explaining together the decline of inner cities and the consequent peri-urban growth (He & Zhang, 2023), were more frequently reinforced (and sometimes replaced) with exploratory, multivariate analyses of developmental paths (e.g. Masini et al., 2019), assumed to be increasingly articulated over space and heterogeneous over time (*sensu* Kingsley & Enders, 1975). In advanced economies, and especially in the European continent, these patterns have frequently reflected a development path characteristic of metropolitan regions moving toward entropic – or, in some cases, polycentric – structures (Salvati, 2014). This path led to spatially polarized social functions and diversified economic activities (Kroll & Kabisch, 2012). However, informal cities, like the ones found in Mediterranean Europe, generally deviate from this pattern (e.g. Cuberes and González-Val, 2017), producing relatively compact urban landscapes that evolve sometimes towards settlement scattering and functional entropy (De Rosa & Salvati, 2016; Economou, 1997; Rodríguez-Pose & Fratesi, 2007). An in-depth investigation of these peculiar development paths - compared to more traditional (and regulated) models observed in Western Europe - contributes to shed light on the major drivers of urbanization and suburbanization, clarifying socioeconomic dynamics in de-regulated and self-organized metropolitan areas (e.g. Coccossis et al., 2005).

Based on these premises, the present study assumes local development as a multivariate process made up of distinctive (e.g. social, economic, territorial, political) dimensions (Di Feliciantonio & Salvati, 2015). Local development was investigated assuming a given metropolitan region as constituted of two interacting districts, inner city and the surrounding periphery (e.g. McCombie et al., 2018). The multivariate relationship inherent in the development path of these two districts was assumed at the base of bi-directional mechanisms of socioeconomic impulses' propagation, fuelling local development during both urbanization and suburbanization (Makarem et al., 2016). The Athens' metropolitan region (Greece) – further divided in the Greater Athens' area (hereafter the 'center') and the rest of Attica (hereafter the 'periphery') – was the area investigated in our study, using a comprehensive set of 14 socioeconomic indicators made available separately for both districts on a year base over a sufficiently long time series (1966–2008). Indicators were selected with the aim at representing the different dimensions of metropolitan development mentioned above (Pili et al., 2017; Rontos et al., 2016; Zambon et al., 2019). A two-block Partial Least Squares (tPLS) regression was run on both indicators' sets (i.e. reflective of both 'central' and 'peripheral' dynamics) assuming the existence of bidirectional, multivariate relationships between local development paths of these areas (Morrisen, 2005). This strategy provides an integrated, comprehensive vision of (apparent and latent) mechanisms of growth and change at the regional scale (Wold, 1975), quantifying in turn the intrinsic degree of interaction between local development paths.

2. Materials and methods

2.1. Study area

Attica is the densest (administrative) region in Greece, corresponding with the Nuts-2 level of the European Territorial Statistic Nomenclature and covering nearly 3800 km^2 of mainland and insular districts (Pili et al., 2017). The region overlaps – for most of its area – with the boundaries of the 'Urban Atlas' (metropolitan) region of Athens, the capital city of Greece (European Environment Agency, 2010). Attica includes more than 110 mainland municipalities - both urban and rural - and some (small and medium) islands in the Saronikos gulf (Aegean Sea). Taken together, the region mostly consists of mountains bordering the flat area that hosts the Greater Athens' agglomeration (administered by 58 municipalities). Being located outside the Greater Athens' area, the coastal plains of Messoghia (including Marathon) and Thriasio host the largest proportion of rural population in Attica (Morelli et al., 2014).

To investigate suburbanization patterns and economic (both synchronic and delayed) impulses of urbanization, two areas ('inner city' and the surrounding 'periphery') with distinctive demographic, economic, and territorial characteristics (respectively corresponding with Greater Athens and the rest of Attica) were identified and selected as the elementary spatial units of this study (Cecchini et al., 2019). Long-term urbanization and suburbanization were both documented in earlier studies (Egidi et al., 2020) as socioeconomic processes depending on territorial dynamics observed both in the central city and in the surrounding locations since the immediate aftermath of World War II (Rontos et al., 2016). In the mid-1960s, the Greater Athens' area was a dense (4050 inhabitants/km^2) and dynamic urban district acting as an attractor of population from low-density, marginal districts all over rural Greece. In the same period, the rest of Attica played a negligible role in the economic scene of the country, maintaining the original trait of a rural region (60 inhabitants/km^2) surrounding Athens (Arapoglou & Sayas, 2009). However, the rest of Attica grew rapidly as far as economic activities and population were concerned, acquiring more recently a dominant role in the country (Salvati et al., 2013) and becoming more tightly connected with the intrinsic dynamics of Athens and the surrounding central locations (e.g. Piraeus, Maroussi, Kallithea, Peristeri).

2.2. Indicators

A total of 14 contextual indicators covering the time period between 1966 and 2008 were made available on a year base from official statistics distinguishing two sub-areas: the Greater Athens' area ('center') and the rest of Attica region ('periphery'). Indicators were derived from elementary data routinely collected by ELSTAT and reorganized into a geo-database (www.nomoi.gr) disseminating a vast set of information on the economic performance of Greek regions (NUTS-2 level) and prefectures (NUTS-3 level). Indicators were subdivided into four dimensions representative of distinctive issues of metropolitan development (e.g. Salvati and Sabbi, 2016): (i) population and job market (3 indicators); (ii) land-use and settlements (4); (iii) economic performance (3); and urban functions (4). This ensemble was selected to provide a multivariate description of metropolitan development with negligible redundancy (i.e. having a Variance Inflation Factor always below 10 for each individual variable). As documented in earlier studies (e.g. Morelli et al., 2014; Pili et al., 2017; Rontos et al., 2016; Salvati & Serra, 2016), these indicators represent – explicitly or implicitly – different and relevant aspects of urban growth (e.g. agglomeration, scale, accessibility, and amenities) in the study area (Gavalas et al., 2014; Zambon et al., 2017; Lestegás, 2019).

Population and job market were described considering demographic density (residents per km^2, hereafter 'Den'), natural population balance (i.e. the absolute rate of births to deaths, 'Nat'), and the rate of participation (%) in the job market ('Par'). Land-use and settlements were depicted quantifying the ratio of new dwellings per 100 inhabitants

('New'), the average number of rooms per new dwelling ('Roo'), the share of cropland (%) and of irrigated land (%) in total landscape ('Cro' and 'Irr'). Economic performances were assessed considering the share (%) of household electricity consumption in total use ('Ele'), the absolute ratio of expenditures to revenues of local treasures, i.e. municipalities ('Exp'), and the number of cars per 100 inhabitants ('Acc'). Finally, metropolitan functions were estimated using the number of road accidents per 1000 inhabitants ('Car'), and the density (per km^2) of three activities/functions: drugstores, hospital beds, and doctors.

Taken together, the selected indicators reflect Athens' development between the mid-1960s and the mid-2000s (Morelli et al., 2014; Rontos et al., 2016; Zambon et al., 2019). Data encompassed two sub-periods with different socioeconomic contexts and territorial characteristics (Zambon & Salvati, 2019): (i) a growth wave dominated by compact urbanization with huge population increase (mid-1960s to mid-1980s) and (ii) a stage reflecting spatially dispersed (low-density) settlement expansion with stable or slightly increasing population (mid-1980s to mid-2000s). The most recent period (from the late 2000s to nowadays) was excluded from the analysis since it was representative of an abrupt recession causing inherent perturbations in both housing and job markets (Salvati & Serra, 2019), and determining significant (non-linear and less predictable) impacts on local development (Di Feliciantonio et al., 2018). Depending on exogenous shocks, such impacts seem to be correlated neither with long-term economic dynamics nor with (short-term) structural change whose investigation is within the scope of this study (Ciommi et al., 2019).

2.3. Data analysis

This study defines local development as a complex and multivariate process showing heterogeneous temporal patterns that reflect convergent (or divergent) transformations in metropolitan regions (e.g. Timár & Váradi, 2001; van Criekingen, 2010; Shafizadeh-Moghadam & Helbich, 2015). We specified the intrinsic relationship between multivariate development paths in neighboring places as:

$$d(Y_1) \approx f(\bullet) \approx d(Y_2) \quad \text{(Equation 1)}$$

Where d (Y_1) and d (Y_2) represent separate developmental processes approximated with the development indicators mentioned above and observed over time in both areas 1 and 2 and $\approx f(\bullet) \approx$ indicates a functional operator quantifying the multidimensional, bidirectional relationship between the two long-term development paths (Wold, 1975). Convergence (or divergence) in local development paths over time was evaluated specifying an econometric (multivariate) model that consider two data matrices constituted of 14 socioeconomic indicators representative of local dynamics in central and peripheral areas of the same metropolis (as mentioned above) between 1966 and 2008. Some preliminary steps were carried out in order to prepare the empirical data for multivariate analysis, as follows.

2.4. Data standardization

Descriptive statistics, exploratory time series approaches, and parametric/non-parametric (bivariate) correlations were carried out in order to control for (and possibly remove) the temporal structure of the input matrices, allowing a multivariate analysis of development indicators (Ciommi et al., 2019). Univariate time-series analysis based on standard coefficients of temporal autocorrelation (both total and partial) delineated a significant time structure, at least for some variables (Salvati, 2022). However, the results of partial autocorrelations detected significant coefficients only at lag-1 and, consequently, the temporal structure in both data matrices was removed through computation of first-differenced time series; all indicators were included in this elaboration. Autocorrelation in these newly elaborated time series resulted to be insignificant for all indicators and spatial locations (Zambon et al., 2019).

Subsequently, a pair-wise correlation analysis comparing parametric (Pearson) and non-parametric (Spearman) coefficients (i.e. considering together sign, intensity and significance) was run on first-differentiated time series with the aim at testing linear and non-linear relationships among the individual dimensions (i.e. indicators) of local development (e.g. Zambon & Salvati, 2019). In line with earlier studies, similarities in the empirical distribution of both Pearson and Spearman coefficients demonstrated the existence of a sequential process of local development in the study area, with linear interactions among individual components of metropolitan growth (Rontos et al., 2016). Taken together, these results justifies the application of a multivariate approach oriented toward a multi-block regression analysis of developmental paths in inner city and the surrounding periphery (Morelli et al., 2014).

Instead of finding hyper-planes of maximum variance between the response and independent variables, multi-block analyses identify a linear regression model projecting the predicted variables and the observable variables to a new space (Henseler, 2010). Because both the X and Y data are projected to new spaces, this family of methodologies recalled the bigger group of 'bilinear factor models' (Rohlf & Corti, 2000). In other words, such analyses define the fundamental relations between two matrices (Y_1 and Y_2), i.e. a latent variable approach to modeling the covariance structures in these two spaces, extracting the multidimensional axes in the X space that explains the maximum multidimensional variance in the Y space.

2.5. Partial Least Squares (PLS) regression

Taken as a technique oriented to "model construction and evaluation when theoretical knowledge is scarce" (Wold, 1980), Partial Least Squares (PLS) regression was considered suitable to delineate the intrinsic, multidimensional and bi-directional relationship between developmental processes in different areas of the same metropolitan region (Egidi et al., 2020). Additionally, the analysis aimed at quantifying the importance of economic (and non-economic) drivers of urbanization and suburbanization at the base of metropolitan transitions in the study area (Kmenta & Ramsey, 2014). PLS regressions provide particularly reliable results when predictors' matrix has more variables than observations, and when there is an evident multi-collinearity among Y_1 and Y_2 values.

A two-block Partial Least Squares regression (tPLS) was adopted here as an appropriate statistical procedure selecting latent axes with an explicit linkage with the input variables (Helland, 1990). tPLS works with an operational framework grounded on Principal Component and Canonical Correlation philosophy (Kroonenberg, 2008), managing together data redundancy and serial autocorrelation in a multivariate distribution of observations (Esposito Vinzi & Russolillo, 2013). Making spatio-temporal patterns characteristic of different variables comparable on a few significant 'instrumental variables', this analysis' strategy allows an indirect measure of the extent to which two local development paths interact to ensure a metropolitan system's functioning under multiple equilibriums (Cassel et al., 1999).

Seen as an ordination method comparable with a traditional factor analysis, tPLS is aimed at maximizing covariance between two sets of covariates on the same observation conditions. The algorithm run in this study follows Rohlf and Corti (2000). Considering the partition of the overall data matrix Y into Y_1 and Y_2 (the two indicators' blocks reflecting development paths in inner city and periphery, respectively), with p columns corresponding to the number of selected indicators (constant in both areas), the correlation matrix R of Y can be partitioned as:

$$R = \begin{bmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{bmatrix} \quad \text{(Equation 2)}$$

The algorithm mentioned above run a singular value decomposition

of the matrix $\mathbf{R_{12}}$ of bi-directional correlations across the two blocks as follows:

$$\mathbf{R_{12}} = \mathbf{F_1 D F_2'} \quad \text{(Equation 3)}$$

Where **D** contains the singular values λ_i along the diagonal, $\mathbf{F_1}$ and $\mathbf{F_2}$ respectively contain the loadings for block 1 and 2. Being a subjective analysis not grounded on hypothesis testing, the selection of significant axes was based on a priori thresholds in accordance with earlier studies (Egidi et al., 2020). The explained covariance is calculated as the amount of covariance explained by each extracted axis, in percentage of the total covariance.

2.6. Regression outputs and graphical analysis

Regression results allow an explicit evaluation of changes over time in the position of each unit (development indicators) and case (years). Indicators' loadings and years' scores were analyzed together in reference with individual axes when defining independent dimensions of local development in the study area (Salvati & Serra, 2016). To delineate convergent and divergent behaviors for the individual indicators, only loadings contributing significantly to metropolitan development were considered. More specifically, a similar loading (both intensity and sign) on the same axis indicate a convergent contribution of the examined indicator to long-term metropolitan development in both inner city and periphery. Similar loading intensity with opposite sign instead represents an indicator contributing to metropolitan development in a divergent way between neighboring areas. Axis' scores (referring to the individual observation years) delineate trends over time in metropolitan development. By plotting scores referring to central and peripheral areas for the same axis, a y = x line was traced to illustrate a balanced development path in both areas. Years placed systematically above or below the line indicate a higher contribution to metropolitan growth of a specific area (inner city or periphery).

Being standardized for construction, scores may finally provide a summary analysis of differential development paths computing the absolute difference (year by year) of the scores assigned to inner city and periphery. Positive differences delineate a net contribution of peripheral areas to metropolitan development while negative scores indicate the reverse pattern. The prevailing dimension of metropolitan development (profiled with the indicators associated to each tPLS axis) was identified over time plotting pair-wise the scores of Axis *m* and *m* + *1*; the y = x line indicated a balanced contribution of both areas to metropolitan development.

3. Results

Considering together the two datasets delineating the long-term development path of both inner city and the surrounding periphery in the Athens' metropolitan region, two-block Partial Least Squares regression has identified 3 axes representing the optimal (multivariate) relationship between the two matrices under investigation – thus characterizing the multidimensional set of interactions between socioeconomic indicators. The three axes explained, as a whole, 72% of the overall variance of the double matrices' system. In particular, Axis 1 explained 33.9% of the overall variance and was characterized by a significant correlation between the two matrices (downtown *vs* periphery) with Bravais-Pearson moment product (linear) coefficient equal to 0.79, and Spearman non-parametric co-graduation coefficient equal to 0.88. Axis 2 explained 23.1% of the overall variance and showed an equally significant correlation between the two matrices (Pearson coefficient = 0.74; Spearman coefficient = 0.76). Finally, Axis 3 explained 14.5% of the overall variance, assuring in turn a very high correlation between the two matrices (Pearson coefficient = 0.81; Spearman coefficient = 0.82). Similar correlation coefficients (both parametric and non-parametric) confirm the dominance of linear relationships in the whole dataset. All axes represent both convergent and divergent behaviors for the individual indicators of local development (Table 1). In other words, long-term metropolitan development was decomposed in individual components associated with indicators reflecting distinctive socioeconomic dynamics in central and peripheral areas.

3.1. Demography and economic activities fueling divided metropolitan development (Axis 1)

As far as the structure of Axis 1 (indicators' loadings and years' scores), the socioeconomic indicators with a decreasing trend over time received positive loadings to the axis, and indicators showing a continuous increase over time received negative loadings. Although with different intensities and opposite loading signs, natural population balance (Nat) and the density of drugstores (Dru) were associated with Axis 1, suggesting that such variables characterized the local development paths of both downtown and the surrounding periphery. Despite natural population balance decreased more or less slowly, following a progressive increase of deaths and a latent contraction of births, the loading of Nat to axis 1 was slightly higher in peripheral areas, reflecting a higher demographic dynamism typical of suburbs all over the study period. Diverging loading signs outlined how Nat and Dru moved in the reverse direction over time, meaning that a moderate population shrinkage coincided with an increased concentration of commercial activities. These findings may also reflect the expansion of malls typical of the suburbanization stage and involving both central and peripheral areas in Athens.

According with the results illustrated in Fig. 1 (left), loadings of per cent share of cropland in total landscape (Cro), density of private cars per inhabitant (Car), density of medical doctors per inhabitant (Doc), and the rate of electricity consumption (Ele), showed substantial differences between downtown and the surrounding periphery. Irrespective of loading's sign, a significant loading in a given area and an insignificant loading in the neighboring area characterized these variables. Plots in Fig. 1 identified graphically such indicators as placed outside the y = x diagonal line. The indicators placed along the diagonal

Table 1
Distribution of significant ($p < 0.05$) loadings on selected tPLS axes by indicator and metropolitan area.

Indicator	Inner city			Periphery		
	Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3
Population density						
Natural balance of population	0.38			0.59		
Job participation rate						
Density of newly built-up dwellings		−0.74	−0.32		−0.52	−0.35
Average number of rooms in new dwellings		−0.43				
Per cent share of cropland in total landscape	0.38					
Per cent share of irrigated land in total cropland						
Per-capita electricity consumption				−0.39		
Density of private cars	0.35					
Density of road accidents			−0.77		0.40	−0.52
Ratio of expenditure-to-revenues of local treasures					−0.41	0.32
Density of hospitals						−0.33
Density of medical doctors	−0.39				−0.40	
Density of drugstores	−0.51		0.33	−0.51		−0.37

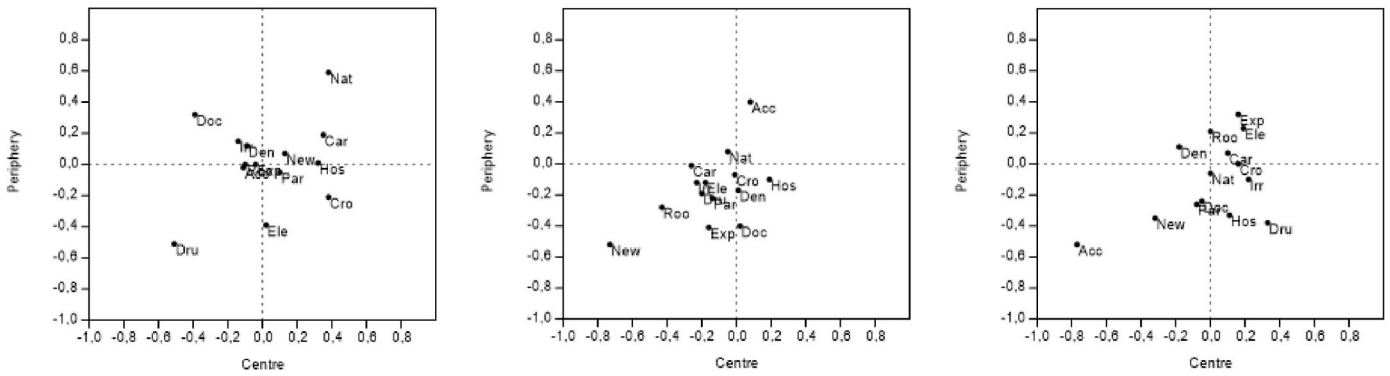

Fig. 1. Distribution of tPLS loadings by indicator, district, and axis (1: left; 2: middle; 3: right), see text for acronyms.

line and outside the axes' origin (y = 0, x = 0) showed a coherent path in both areas (Nat, Dru). Indicators such as Par, New, Den, Acc, Irr, and Exp were not significantly characterized along Axis 1 (i.e. were placed close to the axes' origin), neither downtown nor in the surrounding periphery.

A marked decline was characteristic of cropland dynamics in the inner city – completely disappearing at the end of the 2000s. Conversely, a considerable stock of cropland persisted in the surrounding periphery. A similar trend was observed for the density of private car – decreasing weakly downtown and increasing more rapidly in the surrounding area. Being negatively associated with Axis 1 (downtown), urban functions such as the density of medical doctors consolidated in the inner city, but not in the periphery. By contrast, electricity consumption rates increased significantly in the district outside the Greater Athens' area, as the negative coefficient with Axis 1 clearly documents.

An intense acceleration of socioeconomic dynamics was observed in more recent years (Fig. 2, left), with the highest contribution to peripheral development being associated with specific years (1981, 1987, 1990 and 2001). All these years showed a substantial deviation from the y = x line indicating a coordinated development path in both areas. All in all, Axis 1 indicated a specific development dimension based on the interaction between demographic growth or decline and the expansion of economic activities at differential rates downtown and in the surrounding periphery. However, despite an intense suburbanization, some key functions (such as the density of medical doctors) remained associated with inner cities. The 'development' component illustrated through Axis 1 evidenced that suburbanization was primarily driven by population change and consolidation of activities on the fringe, lacking in an effective territorial re-balance of specific (upper) socioeconomic functions, that remained centralized downtown.

3.2. Divergence in local housing markets at the base of latent suburbanization (Axis 2)

The structure of Axis 2 in terms of indicators' loadings and years' scores was relatively more simple than that characteristic of Axis 1 (see above). Axis 2 delineated a dimension of local development associated with the expansion of housing markets in both central and peripheral areas. The density of new dwellings (New) per 100 inhabitants (increasing moderately over time all over the Athens' metropolitan region) received a negative score in both the inner city and the surrounding periphery (higher downtown). While decreasing more evidently in the inner city, Dwelling size (i.e. the average number of rooms per new dwelling: Roo) received a moderately negative loading in this area. These findings suggest how the construction industry was, together with population growth and expansion/concentration of economic activities, at the base of recent processes of large-scale metropolitan development in Athens. The housing market, however, manifested some local peculiarities because of the demand of small-size dwellings increased downtown and, in turn, the demand of large houses increased in the surrounding periphery. These processes may reflect (i) inner city gentrification and (ii) suburbanization of traditional family nuclei, in line with the empirical evidence of earlier studies.

With specific reference to peripheral areas, Axis 2 resulted to be correlated negatively with the ratio of expenditures-to-revenues of local treasures (Exp) and the density of medical doctors (Doc). Conversely, the density of road accidents was positively correlated with the same axis. Taken together, these results made the differential development paths of downtown and the surrounding periphery clearer (Fig. 2, middle plot). Concentration of specific urban functions over fringe locations and a more dynamic local finance (with total expenditures systematically overpassing total revenues) characterized Athens' suburbanization. Compared with Axis 1, tPLS outcomes illustrated in Fig. 2 (middle plot) indicated a more balanced development path in the study area. Showing

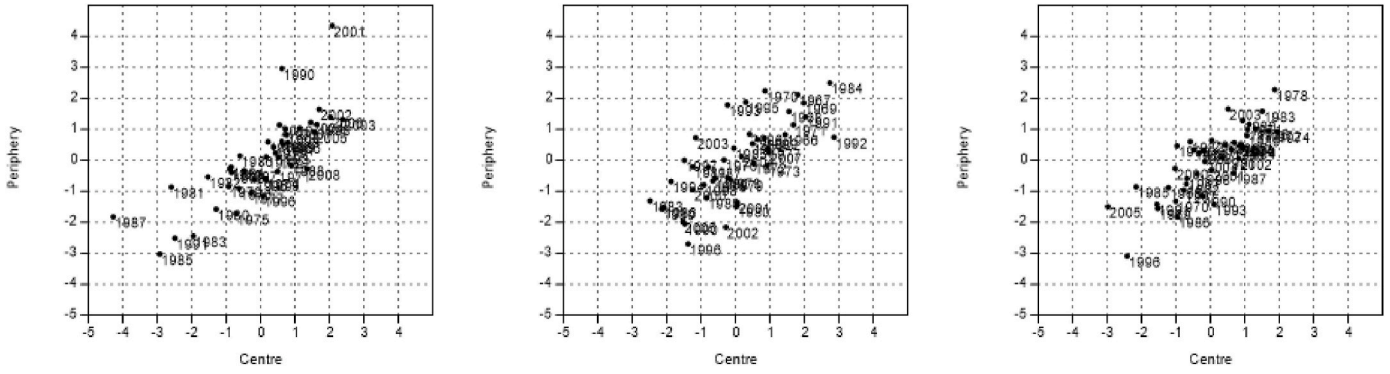

Fig. 2. Distribution of tPLS scores in central and peripheral areas by year, district, and axis (1: left; 2: middle; 3: right).

a substantial deviation from the x = y line (that indicates a coordinated development path in both areas), the highest contribution to peripheral development was provided by a couple of recent years (mainly 1993 and 2003). However, close years (e.g. 1992, 1996, 2002) seem to provide a net contribution to inner city development, evidencing a substantial heterogeneity in local development paths associated with Axis 2.

3.3. The divided distribution of economic functions as a consequence of urban congestion (Axis 3)

The structure of Axis 3 in terms of both loadings and scores delineates a more balanced and (temporally coordinated) development path between inner city and the surrounding periphery (Table 1). Axis 3 basically delineated a process of metropolitan growth based on agglomeration and urban congestion: the number of newly built-up dwellings (New) and road accidents (Acc) received negative loadings for both inner city and periphery. Conversely, the concentration of selected economic activities (density of drugstores, Dru) received significant loadings with opposite signs downtown and in the surrounding periphery (Fig. 1, right). Additionally, the ratio of expenditures-to-revenues in local treasures (Exp) and the density of hospitals received respectively positive and negative loadings, being significant only in the periphery. Taken together, these results indicate a differential development path as far as accessibility, scale, and functions are concerned. Compared with Axes 1 and 2, tPLS outcomes illustrated in Fig. 2 (right plot) indicate a quite balanced development path in the study area. The highest contribution to peripheral development was provided by a couple of recent years (1985, 2003, 2005), confirming the empirical findings presented above. All in all, these results delineate the consolidation of suburbanization processes since the mid-1980s, in line with the evidence of earlier studies.

3.4. A summary analysis of local development paths

Standardized axis scores provided a summary analysis of long-term development paths separately for inner city and periphery. Fig. 3 illustrates the evolution over time in the scores' difference between the two areas. Positive scores delineate a net contribution of peripheral areas to local development while negative scores indicate the reverse pattern. Considering the three axes separately, results coherently indicate a differential, positive contribution of peripheral areas to metropolitan development in more recent decades, especially in the 1980s (Axis 1 and, less markedly, Axis 2 and 3), 1990s (Axis 2 only) and 2000s (Axes 1 and 3). These findings suggest the consolidation of suburbanization processes since the early 1980s in Athens, being characterized by the three dimensions of local development identified above.

Finally, the prevailing dimensions of metropolitan development over time were better identified in Fig. 4, considering the y = x as a proxy of balanced contribution to the overall socioeconomic dynamics in the study area. Axis 1 contributed more than Axis 2 to metropolitan development in both 1990 and 2001, and the reverse pattern was observed for 1993 and 2003. Axis 2 contributed more than Axis 3 to metropolitan development in both 1993 and 2003, and the reverse pattern was observed for 1980, 1992, and 2005. In general, the contribution of individual dimensions of growth was largely differentiated over time. These findings suggest a considerable heterogeneity of development processes in more recent years – a well-known development trait characteristic of suburbanization waves.

4. Discussion

By recapturing a rural way of life without losing the main advantages of urban living (Mlejnek et al., 2020; Morelli et al., 2014; Petrov & Marinov, 2020), suburbanization following urbanization was seen as a response to structural issues downtown (e.g. greater housing prices, overcrowding, physical degradation of buildings and infrastructures, environmental pollution, summer heating, poor greening and services for childhood, crime spreading). Suburbanization was also interpreted as the outcome of regional policies promoting employment (Heider & Siedentop, 2020) and capital accumulation (Zhou & Ma, 2000) at the fringe of dense cities and, less frequently, as a result of spatial planning indirectly stimulating economic, social, and demographic homogeneity (Haase et al., 2010; Kabisch & Haase, 2011; Makarem, 2016). This process depends on specific territorial contexts and social forces active at various spatial scales (e.g. Cividino et al., 2020; Dahan & Tsiddon, 1998; Timár & Váradi, 2001). These factors possibly reinforced each other as a function of a (more or less) strict interplay with the economic dynamics characteristic of the gravitation basin they belong to (Hale & Moberg, 2003; Torrado et al., 2021; Wang & Dong, 2022).

With this perspective in mind, the empirical results of this study provides, at the same time, a place-based interpretation of urbanization and suburbanization processes (Zhao, 2011), and insights for a more general analysis of long-term metropolitan growth and local development in advanced – but spatially polarized – economies (Di Feliciantonio & Salvati, 2015; Kabisch & Haase, 2011; Makarem, 2016). More specifically, the results of a tPLS regression applied to a comprehensive ensemble of indicators delineating long-term development paths in both central and peripheral areas (Benassi et al., 2020), have revealed spatio-temporal directions of urbanization and suburbanization, quantifying the contribution of specific processes of change to local development (Rodríguez-Pose & Fratesi, 2007; van Criekingen, 2010; Cuberes and González-Val, 2017; Rontos et al., 2020).

Regression analysis has further indicated how changes over time in both economic and non-economic variables may exert a relevant contribution to suburbanization (Haase et al., 2010). The differential time pattern between inner city and periphery observed for service, transport, and economic performance indicators, suggests how economic development was spatially heterogeneous and mostly divided in urban and suburban areas (e.g. Bailey, 2021; Couch et al., 2007; Shen & Wu, 2020). An expanding tertiary sector, and adjustments in the cost of energy and transportation, made the socioeconomic structure of 'inner city' and 'periphery' more balanced since the 1980s, suggesting how urbanization in the 1960s and the 1970s has indirectly fuelled exurban development in the subsequent decades (Di Feliciantonio et al., 2018; Salvati, 2022; Zambon et al., 2019).

Changes in the spatial distribution of key functions and activities have indicated a more dynamic socioeconomic context in suburbs, at least since the mid-1980s (Salvati & Sabbi, 2014). However, in partial agreement with other studies focusing on contemporary Athens – and in partial disagreement with more general studies carried out in other European cities (e.g. Timár & Váradi, 2001; Morya & Ram, 2020; Delmelle et al., 2021) – development of high-technology services exerted a marginal effect on suburban areas. This evidence reflects the economic structure of the city, still oriented toward traditional services, manufacture, and the public sector (Cecchini et al., 2019). While experiencing important socioeconomic changes in the last decades (Pili et al., 2017), the peculiarity of Athens – which is uncommon to other metropolitan realities in the most advanced European countries – was intrinsic in the preservation of a rural profile dominant in suburban places (e.g. Duvernoy et al., 2018). Industrial settlements concentrated in few spatial clusters and slowly expanding services were characterized by high-diversity and territorial heterogeneity at the local scale (Zambon et al., 2019).

The results of the econometric model – properly interpreted in a perspective of metropolitan complexity – have provided a tool identifying latent dynamics of local development and socioeconomic convergence/divergence between urban and rural districts (Makarem, 2016; McCombie et al., 2018; Zambon & Salvati, 2019). More specifically, these findings contributed to specify the bi-directional relationship of local development paths in central and peripheral areas (Aritenang, 2023), suggesting a more comprehensive interpretation of such dynamics as a two-sided piece of urban history (Bailey, 2021; Lee &

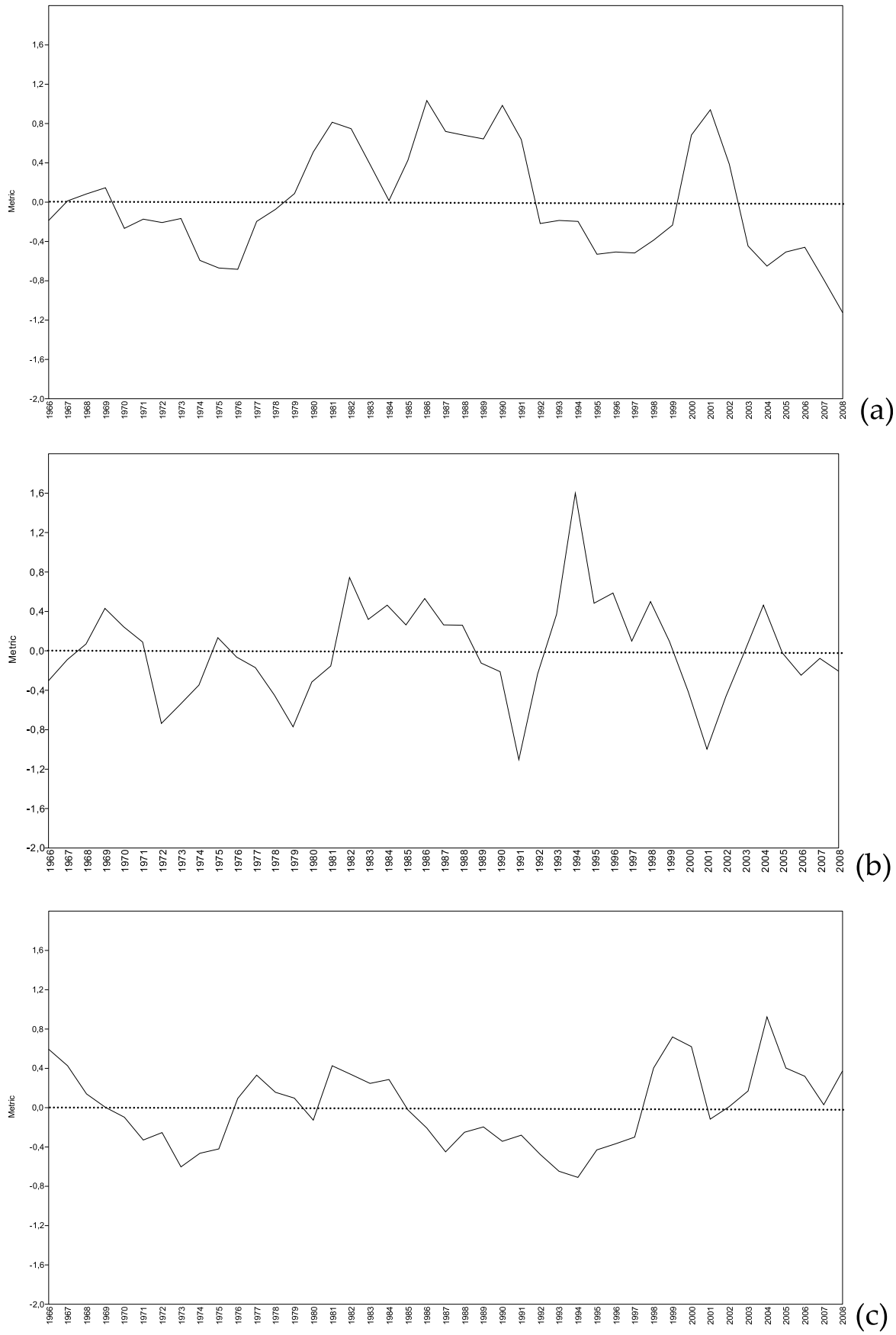

Fig. 3. Standardized tPLS axis scores by year; three-years moving average of the score difference between 'periphery' and 'inner city' (a: Axis 1; b: Axis 2; c: Axis 3); the horizontal line estimates a balanced path of metropolitan development.

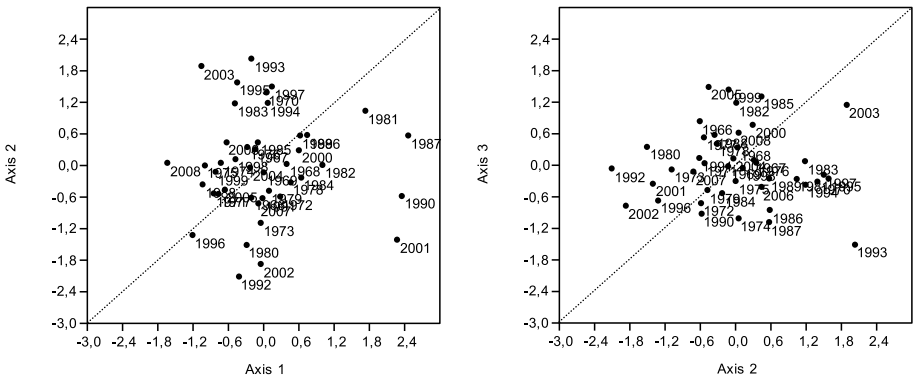

Fig. 4. Relationship between tPLS Axis 1 and 2, and tPLS Axis 2 and 3 (dashed line estimates a balanced path of metropolitan development).

Mason, 2010; Redding, 2022). As a matter of fact, metropolitan development mixed the 'traditional' sequence of urbanization-suburbanization waves (rather well delineated and predicted in the City Life Cycle theory) with counter-intuitive, reverse dynamics reflecting suburbanization (Tian & Mao, 2022). The indirect effects of this process resulted in the latent recovery of central cities after economic decline, demographic shrinkage, and temporary abandonment of productive spaces (e.g. Berliant & Wang, 2004; Carlucci et al., 2018; Morya & Ram, 2020).

Based on a literature review and an empirical application of generalized econometric and multivariate techniques, our work contributes to the study of urban growth and change influencing the level and spatial direction of local development. Basic indicators derived from official statistics and reflecting differentiated mechanisms of urban (and suburban) expansion, reflect the intrinsic complexity of the quantitative information needed to evaluate processes of metropolitan development. Their use in econometric modeling reflects the complexity of the question to be answered and calls for a multi-disciplinary research strategy integrating socio-demographic and economic approaches. At the same time, such approaches require continuously updated, spatially relevant and comparable indicators, capable to describe the possible changes occurred over short time windows. With this perspective in mind, official statistics at both country and supra-national scale (e.g. Eurostat, OECD, FAO, United Nations) should improve the intrinsic quality (e.g. longer time series, spatial details, internal coherency and comparability across countries) of socioeconomic indicators reflecting metropolitan growth and change as a particularly urgent task contributing to inform regional science, urban studies and spatial planning in both advanced and emerging economies. Improvements in a set of basic indicators of urban expansion and exurban development based on official statistics may finally consolidate the use of mixed econometric techniques and exploratory, multivariate approaches – like those adopted in our study. These approaches can be applied to differentiated socioeconomic contexts and territorial conditions with the aim at disentangling the inherent complexity at the base of metropolitan growth.

5. Conclusions

The empirical results of this study aligned with earlier literature indicating temporally continuous – but functionally heterogeneous – expansion of urban centers into adjacent, non-metropolitan areas. This process was frequently associated with industrial decentralization of manufacturing – in pursuit of lower land costs, rising access to modern facilities for rural populations, a latent preference for long-distance commuting, and lower living cost in suburbs – as well as government decentralization policies. However, some specific socioeconomic traits consolidated along half a century were (and still are) peculiar elements distinguishing urbanization from suburbanization – as highlighted in the results of the econometric analysis run in our study. In Athens, these two growth waves seem to differ, at least partly, from those observed in several metropolitan regions of Western Europe; however, the consequences for local development may be generalized, in some ways, to other cities and regions experiencing a similar socioeconomic context. This will help to disentangle the peculiar nexus between spatial patterns of urban growth, regional planning, and processes of exurban development in Southern Europe – which need further comparative investigation and (novel) multi-dimensional approaches to be fully understood.

Delineating the complex behavior of the individual processes (economic, demographic, territorial) underlying local development, the empirical results of our study finally claim for an integrated strategy governing urban expansion and metropolitan growth and change that links spatial planning and social policy at large. While spatial planning encourages the optimal use of land (both urban and rural), enhancing the peculiarity of any territory, social policies – usually enforced at a broader spatial scale, namely administrative regions – may improve living conditions and neighborhood quality. Their operational integration contributes to delineate a more sustainable developmental path in metropolitan regions, diversifying measures that address specific issues in urban and suburban districts.

Availability of data and material

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Authors' contributions

G.Q. and L.S. wrote the manuscript; R.S. and F.E. collected and analyzed the data; A.M.A.A. provided graphical and technical assistance and the bibliographic analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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