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A multi-scalar analysis
of European cities

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A MULTI-SCALAR ANALYSIS OF EUROPEAN CITIES

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ABSTRACT

Medium-sized European cities are facing serious problems in terms of the exploitation of local resources (land, water, air). In this article, we observe existing links between sustainable development and cities' economic and structural features. We adopt a multi-scalar perspective, since the theme of sustainable development involves both urban areas and the wider regions surrounding them. First, we identify clusters of urban areas that are homogenous in structural terms and we then compare these results at different territorial scales. When the sustainable development of the clusters is observed, a clear 'geography of resource exploitation' emerges, consistent with both urban economic and environmental indicators. Then, as a possible response to these problems, we suggest a typical tool adopted by planners: that is, polycentrism. Rather than considering it as a simple morphological feature of European urban systems, we look upon it as a possible mode for the governance of networks of medium-sized cities. In the last section of the paper, we analyse the economic and structural drivers that explain potential for polycentric integration.

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Acknowledgements

1   Introduction

In recent years, European cities have been facing many challenges: the economic crisis affecting their manufacturing sectors, globalization, changes in the local labour market, rapid, deep social changes due to international migration, congestion of local transportation systems, and the heavy use of natural resources (i.e., land, air, etc.). In particular, the exploitation of environmental resources seems to be undermining their sustainable development. Since sustainable development was first defined (World Commission on Environment and Development, 1987), this concept has been applied to a variety of thematic areas, from the environment to society and the economy. Now it is clear that many environmental problems both originate and are experienced most intensely in cities. European institutions are also well aware of the problem: in 2007, the "Leipzig Charter on Sustainable European Cities" was approved (European Union, 2007). Although the Charter is quite generic, it does represent an initial attempt to focus on the sustainability of medium-sized cities.

Unfortunately, in mainstream economics the sustainability of economic systems is not a key concept. Cities are generally considered as dimensionless markets, whose only role is the facilitation of exchanges between producers and consumers[1]. In this paper, we consider cities as open systems for the production and reproduction of both human activities and resources. Therefore a city can be defined as sustainable if and only if it can either reproduce all the resources it uses or internalize the costs of their reproduction. In that sense, cities are quite similar to 'enterprises'.

As geographic location seems to affect economic phenomena, a multidisciplinary approach is required. Economic geography has attempted to underline the importance of spatial location (and land use) in economic phenomena (Fujita *et al.*, 1999). Since the seminal works of von Thunen (1826) and Christaller (1933), location theory has become a central pillar of regional science (Thisse, 2010) and it can be now divided into three subfields: i) spatial competition theory (Hotelling, 1929); ii) urban economics (Alonso, 1964); and iii) economic geography (Krugman, 1991a). In particular, the concept of New Economic Geography (or NEG) explains the geographic location of firms in central regions by identifying of both increasing returns to scale (IRS) and transportation costs. Agglomeration economies[2] (see also Marshall, 1890) work towards agglomeration in locations, while transport costs work towards divergence. The final outcome depends on which of them dominates (Krugman, 1991a; Krugman, 1991b). The application of NEG is quite wide: it can also be applied to urban economics (Krugman, 1993), since in cities the main forces at work are fairly similar[3] (Thisse, 2010).

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[1] In Weber (1979), a city is mainly a fortification and a market. It is also an association of urban citizenry.

[2] See, for example, the existence of "sharing, matching and learning mechanisms", to use the words of Duranton *et al.* (2004).

[3] Both IRS in production and IRS in exchange are relevant to explaining the existence of urban agglomerations (o' Sullivan, 2007). When speaking about transportation costs, we also count commuting costs (Cavailhès *et al.*,

As already stated, NEG introduces a consideration of the spatial dimension to economies and urban trends. However, its implications seem to be much wider. While the core-periphery model is path-dependent and largely self-reinforcing (Krugman, 1991a), the temporal dimension also matters. If cities are processes that require coordination, then institutional activity can shape the regional landscape: institutions (whose role has always been neglected since the time of Adam Smith's "invisible man") can create and relax new constraints, in both the short and the long run. So, both resources and increasing returns to scale, far from being natural phenomena, are sharply modelled by the policies of national and local authorities. Thus institutions matter: they manage public goods (such as the land); they foster rules to regulate sharing; they can promote territories' local identities. They also help to define divisions of labour and determine a region's competitiveness and cohesion. In short, local institutions may foster or hinder the correct reproduction of exploited resources.

While recognizing the role of institutional activity in strengthening cities' sustainability, we do not know which policies may represent best practices. Like markets, institutions may fail. The debate is also still open among European researchers and urban planners. Over the last few decades, interest in polycentrism as a possible form of governance for medium-sized cities has been increasing (Anas *et al.*, 1998; Bailey *et al.*, 2001; Romein, 2004; Meijers, 2005; Cowell, 2010). The concept is quite "vague" (Riguelle *et al.*, 2007, p.195), so there are many different interpretations depending on researchers' viewpoints (Forstall *et al.*, 1997; Kloosterman *et al.*, 2001; Romein, 2004; Riguelle *et al.*, 2007): here, we refer to inter-urban polycentrism (within sub-national regions) as a possible form of integration between medium-sized cities. Analogies to the network theory are clear[4] (Meijers, 2005). In polycentric regions, medium-sized cities are: located in close proximity; historically distinct; lacking a clear leading city; and, as a consequence, independent political entities (Kloosterman *et al.*, 2001). They are also well-connected (Meijers, 2008) and interrelated through co-operation flows (Cowell, 2010).

Historically, the concept of the PUR (Polycentric Urban Region) comes from the direct observation of some regions in North-Western Europe (Bailey *et al.*, 2001): the Randstad, the Flemish Diamond and the Rhein-Rhur area are classic examples. There are also examples of polycentric regions outside North-Western Europe: the Basque Country and the Padua-Treviso-Venice Area and Emilia-Romagna in Northern Italy (Romein, 2004; Cowell, 2010). Moving on from the status of a simple descriptive tool, the PUR concept has often been advocated by policy-makers in the Netherlands[5], Belgium and Germany. It has rapidly developed into a spatial planning tool (Bailey *et al.*, 2001) and has been adopted in national

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2007). In other words, "in urban economics, workers compete for land and then travel to a city's central business districts" (Thisse, 2010, p. 281).
[4] We cannot test network theory's main hypothesis in this paper due to the lack of detailed and comparable data about European urban areas.
[5] Polycentrism has been part of planning documents in the Netherlands since 1958 (Cowell, 2010).

planning frameworks (Federal Ministry for Regional Planning, Building and Urban Development, 1993; Albrechts, 1998; Priemus, 1998). Since 1999, with the "European Spatial Development Perspective", polycentrism has also become a regulatory tool for the achievement of the policy-objectives of the European Union[6] (CSD, 1999; ESPON, 2005).

In other words, polycentrism is now considered a best practice (Governa *et al.*, 2005). It offers a sound basis for strategies that promote the "advantages of stronger interaction between neighbouring cities to develop specialized and complementary assets, while avoiding large-scale urban sprawl and destructive territorial competition" (Bailey *et al.*, 2001, p. 698). The fact that there is a "strong 'anti-sprawl' agenda built into the PUR idea" (Bailey *et al.*, 2001, p. 698) provides confirmation that PURs and sprawl come from opposite policies, based on different perspectives[7].

Moving on from these achievements, the purpose of this paper is to study the European urban system in an interdisciplinary way. We identify different European urban types by adopting both multiscalarity as our main methodology and polycentrism as the hypothesis to be tested. As cities are open systems, we analyse them at different territorial levels to identify the types of cities that are experiencing an unsustainable mode of growth. Later, talking about best practices, we test whether these cities may also share a potential for polycentric integration. The structure of the paper is as follows. Section 2 briefly outlines the sample of cities and the data that can be used to perform a multi-scalar analysis. In section 3, a cluster analysis is performed. Different types of cities are identified on the basis of structural indicators. The results obtained are tested at different territorial scales, to verify multiscalarity. Exploitation of natural resources is also tested. In section 4, we define a polycentric integration potential for European cities and, through a regression analysis, we link it to cities' main structural features. In section 5 we put forward some concluding remarks, highlighting some possible future developments.

2   Describing European urban areas at different territorial levels: the sample of cities and the data used

Europe has always been a continent of cities (Weber, 1979; Le Galès *et al.*, 2001; Le Galès, 2006) and it is in cities that the most intense problems of the exploitation of resources (i.e., land, water and air) can now be seen. In Europe there are different types of cities that differ sharply in terms of exploitation of resources and sustainability: monocentric

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[6] In particular, ESDP argues for the need for balanced and polycentric patterns of urban development within Europe: polycentrism should imply both a more balanced system of metropolitan regions, city clusters and city networks and an integrated spatial development strategy (CSD, 1999).

[7] Critics of suburban development argue that in the U.S.A. the spread of sprawl is the result of a specific mix of policies, i.e., the way mortgage interest and property taxes are dealt with in the federal income tax code, the extensive highway subsidies, low gasoline taxes and rigid suburban zoning codes (Richardson *et al.*, 1999).

megalopolises (Paris, London, Madrid), polycentric urban systems of medium-sized cities in central regions (the Randstad, Northern Italy), and peripheral towns in rural areas.

Although a comparative analysis of the exploitation of resources in European cities is one of the paper's main aims, we do not classify cities into types on the basis of their degree of sustainability. Instead, we analyse their economic and structural features at different territorial scales. For that reason, we merge urban structural data from different databases: the Urban Audit (Eurostat); the REGIO-Eurostat database; and data collected by the ESPON Project 1.1.1 (2005).

The analysis starts from the Urban Audit Database, which collects data for European core cities (LAU-2 level). Due to rather poor data coverage, our analysis is limited to 181 cities in Western European Countries (i.e. EU-15 Member States). In terms of indicators, we collect the following structural variables: *resident population*; *per capita GDP* (in Euro); *unemployment rate*; *proportion of employment in industrial sectors*; *proportion of graduates in population*. To enrich the analysis, two other indicators are added: *multimodal accessibility index*[8] and *total agricultural area (in ha.) per inhabitant*. They do not strictly refer to urban areas as defined above, but they highlight geographic features of the NUTS-3 regions (e.g. Italian *Province*, French *Department*, German *Kreis*) which surround the 181 cities in the sample. (For a more detailed explanation of both the cities and the chosen indicators, see "Appendix – Cities and Indicators"). Although the latest Urban Audit collection round dates from 2006/2007, we use 2001 data to limit the number of missing values. The remaining missing values were replaced by data at the NUTS-3 or NUTS-2 level (the data source is REGIO-Eurostat). We are well aware of distortions deriving from the use of different geographic units. However, we are able to use data from Eurostat only, without mixing data from different national statistical sources.

The second database involved is REGIO-Eurostat. To adopt a multi-scalar perspective, we also collect information for the NUTS-3 regions that contain the 181 cities in our sample[9]. The same variables (i.e., *resident population*, *per capita GDP*, *unemployment rate*...) are collected[10]. The reference year is still 2001, to assure the use of comparable data.

As already stated, multiscalarity is the main methodology adopted and polycentrism is a hypothesis for testing. The ESPON Project 1.1.1 (2005) studies polycentrism in Europe on the basis of the morphological proximity of cities. The building blocks of polycentrism are the

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[8] The index is based on the assumption that the attraction of a destination increases with size (in terms of population or in terms of local market) but declines with distance, travel time or cost. The higher the index, the more a city is connected to other cities, even in different countries. Although multimodal accessibility index data are reported in the Urban Audit Database (Eurostat), the source is © ESPON Database, 2006.

[9] The Urban Audit Database also provides data on Larger Urban Zones (LUZs), which are defined on the basis of commuter flows. They describe cities as so-called Functional Urban Regions (including both the core city and its commuter belt). We do not use LUZs as territorial units, as LUZ data are of substantially poor quality. We adopt the NUTS-3 region as proxy for LUZ, although we know that the former is an administrative unit, so it cannot exactly capture a functional area around a city centre.

[10] By construction, *multimodal accessibility index* and *total agricultural area per inhabitant* are used without distinction for both spatial units of the analysis.

Functional Urban Areas (FUAs), consisting of an urban core and the economically integrated surrounding areas (e.g., local labour markets). Then, for each FUA, the area that can be reached within 45 minutes by car from the centre of the FUA is calculated and approximated to municipal boundaries: this area is labelled the *Potential Urban Strategic Horizon* (PUSH). In the last step, *Potential Polycentric Integration Areas* (PIAs) are identified on the hypothesis that cities with overlapping PUSH areas can be functionally integrated with each other, forming polycentric areas (ESPON, 2005).

In our analysis, we associate each Urban Audit city to a single PIA. By construction, some cities may share the same PIA. For each city, we then calculate: i) the *demographic mass gained through polycentric integration*, that is the population change when the population of the core cities is compared with that of the entire PIA (the greater the increase in this mass, the more a city may benefit from polycentric integration). For cities not belonging to a PIA, we compare the population of the core city and that of its PUSH area; ii) the *number of FUAs belonging to each PIA*; iii) the *status of the city with regards to PIAs*, that is, if a city is a PIA main node; a PIA secondary node; or a node not belonging to any PIA (see "Appendix – Cities and Indicators").

3   A multi-scalar cluster analysis of European cities

As an exploratory analysis to identify different types of European cities, we perform a cluster analysis. This analysis, which is a general approach to multivariate problems (Kaufman *et al.*, 1990), is applied to the 181 cities in our sample and is based on the seven variables collected at LAU-2 level[11]. To show the results in graph form, we adopt a dendrogram, i.e. a tree-like plot where each step of hierarchical clustering is represented as two branches of the tree merging into one (figure 1).

After having analysed the structure of the dendrogram, we can observe eight different clusters[12]. Moving from the left side of the dendrogram, we first come across clusters of Northern and central cities: "powerhouses", "regional poles", "industrial cities" and "capital cities".

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[11] In methodological terms, cluster analysis is performed with a hierarchical algorithm, following an agglomerative method. The dissimilarity matrix is obtained by calculating the Euclidean distances between objects; whereas distances between groups are calculated using Ward's method (Ward, 1963). To avoid distortions deriving from variables that may have different units of measurement, all variables are previously standardized to obtain z-scores (Kaufman *et al.*, 1990).

[12] To highlight similarities between observations, it is important to choose the right cut-off height for the dendrogram. Increasing the height provides larger but less uniform clusters; if it is decreased it, clusters consist of more similar observations, but have less explanatory power. In our case, we can demonstrate that the choice of eight clusters is particularly efficient: if we chose seven clusters, we would obtain much less uniform clusters (i.e., there is a rapid jump in the height at which the branches merge); conversely, choosing nine clusters, would not increase the explanatory power of our analysis.

Figure 1 – Classification of European core cities (reference year 2001)

Cluster analysis at city level (reference year 2001)

Source: Personal elaboration on Urban Audit-Eurostat (2010) and © ESPON Database (2006).

The cities in these clusters are wealthy (especially powerhouses) and they show an above-average accessibility index (see table 1). With the sole exception of the cluster of capitals, all these cities are generally medium-sized. Three other clusters ("rural cities", "peripheral cities" and "underdeveloped cities") cover Southern and peripheral regions (that is, cities in Mediterranean regions, along the Atlantic coast and in Scandinavian countries). They share poor economic indicators and a below-average accessibility index (see table 1). At the right end of the dendrogram, the cluster of "global cities" consists of London and Paris: they differ sharply from other cities in terms of population size, per capita income and proportion of graduates.

Table 1 – The profile of the eight clusters of core cities (reference year: 2001)

		Population	Per capita GDP	Unemployment rate	Employment in Industrial sectors (%)	Proportion of graduates (%)	Accessibility Index	Agricultural area (ha) per inhabitant
Powerhouses (28)	Mean	444,463	44,519	5.5	13.5	26.0	145.8	11.5
	Sd	*273,827*	*10,442*	*2.2*	*5.9*	*5.1*	*27.6*	*11.8*
Regional poles (56)	Mean	490,826	25,466	9.4	14.8	21.5	115.2	14.0
	Sd	*387,872*	*7,183*	*4.1*	*4.5*	*2.7*	*19.1*	*13.5*
Industrial Cities (26)	Mean	258,205	23,841	6.6	23.4	14.1	118.6	19.5
	Sd	*199,435*	*7,229*	*1.7*	*5.9*	*2.2*	*32.0*	*13.8*
Capital cities (3)	Mean	2,957,987	23,371	12.8	12.8	23.7	133.0	5.4
	Sd	*421,146*	*2,945*	*1.8*	*3.0*	*5.6*	*24.6*	*4.7*
Cities in rural areas (20)	Mean	194,859	25,067	9.2	19.9	25.8	72.2	141.4
	Sd	*138,523*	*5,337*	*4.6*	*5.3*	*6.0*	*15.1*	*62.2*
Peripheral Cities (32)	Mean	153,282	17,980	10.6	13.7	18.5	73.5	63.7
	Sd	*81,817*	*5,195*	*3.6*	*4.1*	*2.5*	*15.8*	*25.5*
Underdeveloped cities (14)	Mean	344,660	13,380	22.3	12.8	14.3	82.1	45.3
	Sd	285,724	2,660	5.1	4.1	3.2	16.8	33.6
Global Cities (2)	Mean	6,668,255	57,088	9.1	8.3	33.3	167.0	0.0
	Sd	*712,532*	*18,084*	*3.7*	*0.2*	*0.1*	*12.7*	*0.0*

Source: Personal elaboration on Urban Audit-Eurostat (2010) and © ESPON Database (2006).

As expected, the classification highlights major differences between types of European cities. Unfortunately, some criticisms can be levelled at this classification. Having adopted a small set of structural indicators, we may have ignored some other important discriminating variables. These single aspects do not undermine the general framework of our analysis: the eight clusters differ not only in terms of social and economic features, but also in terms of local sustainability. As noted in the introduction, sustainability and exploitation of resources involve not only administrative cities (LAU-2 level) but also the functional areas surrounding them. To validate the results, a cluster analysis based on data at NUTS-3 level is performed[13]. The dendrogram is not shown here, but the earlier results are also confirmed at the NUTS-3 level. It is possible to identify a group of densely-populated NUTS-3 regions

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[13] Moreover, by performing two similar cluster analysis at different territorial scales, it is possible to overcome a methodological drawback of cluster analysis: that is, the lack of tests for the statistical significance of results. As a matter of fact, by duplicating the analysis, we can compare the obtained results and validate or reject them.

(powerhouses, capital and global NUTS-3), contrasting with less populated NUTS-3 regions (rural and peripheral NUTS-3, underdeveloped NUTS-3, regional poles and industrial NUTS-3). Table 2 shows the profiles of the eight clusters based on NUTS-3 level data.

Table 2 – The profile of the eight clusters of NUTS-3 regions (reference year: 2001)

		Population	Per capita GDP	Unemployment rate	Employment in Industrial sectors (%)	Proportion of graduates (%)	Accessibility Index	Agricultural area (ha) per inhabitant
Powerhouses (33)	Mean	877,393	41,604	4.7	13.6	25.0	143.9	10.5
	Sd	*539,419*	*10,351*	*2.2*	*4.4*	*5.0*	*27.2*	*11.1*
Regional poles (61)	Mean	654,228	26,444	6.7	19.0	21.2	115.5	20.9
	Sd	*366,383*	*6,060*	*2.9*	*3.6*	*3.1*	*24.0*	*19.1*
Industrial NUTS-3 (12)	Mean	723,467	24,633	3.5	29.0	9.6	104.5	27.0
	Sd	*507,061*	*6,924*	*1.3*	*5.3*	*1.3*	*23.4*	*10.8*
Capital NUTS-3 (8)	Mean	3,699,800	22,838	10.1	17.7	21.4	125.4	8.4
	Sd	*1,041,141*	*6,142*	*3.3*	*7.2*	*8.2*	*24.4*	*7.9*
Rural NUTS-3 (15)	Mean	452,860	21,753	7.6	23.9	25.1	65.7	162.4
	Sd	*164,469*	*6,109*	*4.2*	*6.6*	*6.0*	*10.7*	*56.4*
Peripheral NUTS-3 (27)	Mean	673,364	20,211	6.6	17.2	15.3	82.0	58.9
	Sd	*409,831*	*5,043*	*2.3*	*4.3*	*5.4*	*16.5*	*38.1*
Underdeveloped NUTS-3 (23)	Mean	657,839	14,278	17.3	12.0	12.2	74.3	47.2
	Sd	*678,912*	*3,416*	*6.1*	*4.5*	*4.1*	*18.2*	*29.8*
Global NUTS-3 (2)	Mean	9,225,750	41,200	7.0	10.2	33.3	167.0	0.0
	Sd	2,704,754	4,384	0.6	2.5	0.1	12.7	0.0

Source: personal elaboration on REGIO-Eurostat (2010) and © ESPON Database (2006).

These results validate our classifications: both types of clusters and their composition are largely confirmed when the territorial scale is changed. Table 3 shows the numeric cross-composition of clusters: 123 cities (i.e., 68% of the sample) are distributed along the main diagonal of the matrix (that is, they are classified in the same group in both analyses). These results allow us to conclude that both data from the Urban Audit – Eurostat (2010) and data from the REGIO - Eurostat database (2010) validate a similar pattern of urban types across Europe (table 3).

**Table 3 – Cross composition of clusters based upon core city data and NUTS-3 data.**

		NUTS-3 REGIONS							
		Global	Capital	Power-houses	Regional poles	Industrial	Under-developed	Peripheral	Rural
CORE CITIES	Global	2							
	Capital		3						
	Powerhouses			25	3				
	Regional poles		5	8	37	2	1	3	
	Industrial				13	10		3	
	Underdeveloped						13	1	
	Peripheral				5		9	18	
	Rural				3			2	15

Source: personal elaboration on Urban Audit-Eurostat (2010), REGIO-Eurostat (2010) and © ESPON Database (2006).

Another validation of our findings comes from direct observation of the geographic distribution of cities and NUTS-3 regions in different clusters (figures 2 and 3): stability in clusters' composition is clear, even when the scale of analysis is shifted.

When we observe the geographic distribution of clusters, further considerations emerge. For example, we note that the NUTS-3 level analysis may be biased by differences in national administrative structures. In Germany, the Netherlands and Belgium, NUTS-3 regions are generally very small (in Germany, NUTS-3 level and LAU-2 level coincide in many cases); whereas in peripheral countries they are much larger in area.

Figure 2 – Powerhouses, regional poles and industrial cities (a) and capital, global, rural, peripheral cities and underdeveloped cities (b) in Europe (reference year: 2001)

a)   b)
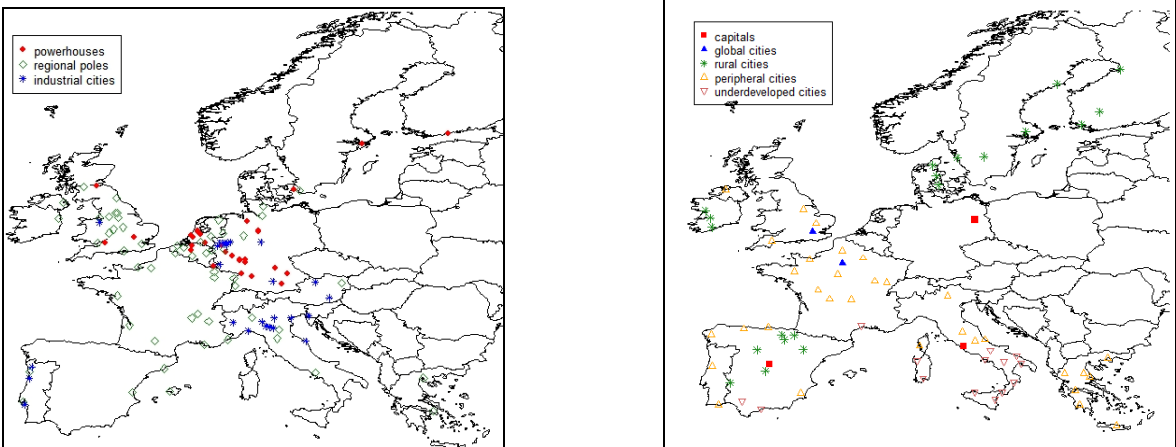
Source: Personal elaboration on Urban Audit-Eurostat (2010) and © ESPON Database (2006).

Figure 3 – Powerhouses, regional poles and industrial NUTS-3 (a) and capital, global, rural, peripheral NUTS-3 and underdeveloped NUTS-3 (b) in Europe (reference year: 2001)

a)   b)
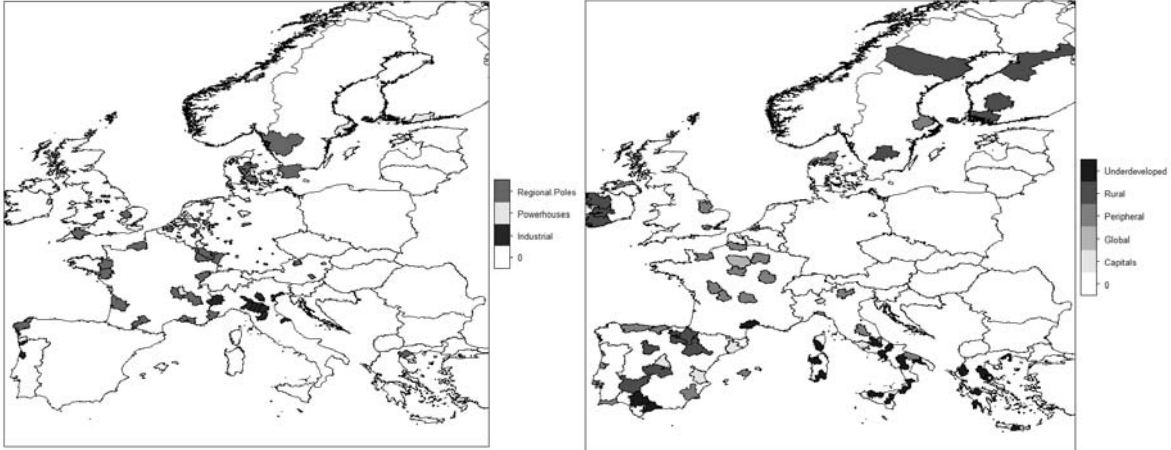
Source: personal elaboration on REGIO-Eurostat (2010) and © ESPON Database (2006).

Figures 2 and 3 also show that it is possible to distinguish two main groups of clusters on the basis of their location. All cities and NUTS-3 regions in the clusters of powerhouses,

regional poles and industrial urban areas are concentrated in the central regions of the continent. So, we can suppose that these three clusters also share other features, especially in terms of sustainability, since they are located in regions with heavy anthropic pressure and massive exploitation of resources.

This hypothesis can be partly tested by analysing some features of the cities in these three clusters. The variables used in cluster analysis are also good proxies of the degree of exploitation of local resources in European cities. Leaving out cities that are not stable in two classifications, we focus our attention on the so-called stable cities[14]. Among them, the groups of stable powerhouses, stable regional poles and stable industrial cities share three common features.

Firstly, these groups consist of medium-sized cities, whose importance for the cohesion and competitiveness of the European urban system is recognized by the European Union (see European Union, 2007; ESPON, 2006). Secondly, they share dynamic labour markets, maybe differing in terms of manufacturing employment or proportion of graduates, but all enjoying the lowest unemployment rates across Europe. Lastly, in terms of urban environment, these cities show a heavy use of natural resources. The area of agricultural land is very small (generally, less than 50 ha. per inhabitant) and, conversely, these cities generally show an above-average multimodal accessibility index. These are good indicators about the 'infrastructuration' of these areas and the heavy anthropic pressure on local resources which is undermining their future growth.

Figure 4 shows these findings by means of box plot graphs. As already said, only stable cities are considered, so the horizontal line shows the average value for the 123 cities included. In colour, we highlight the clusters of powerhouses, regional poles and industrial cities. This analysis confirms that these cities are exploiting natural and human resources (both at core city level and at NUTS-3 level) in an unsustainable way. The geographic location of these 72 cities strongly confirms this hypothesis (figure 5): a clear 'geography of exploitation of resources' is obtained, as all those cities are located in regions near the centre of Europe, where both economic activity and pollution levels are at their highest.

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[14] That is, LAU-2 level and NUTS-3 level cluster analysis. We are leaving out about a third of the total sample, as previously noted.

Figure 4 – Anthropic pressure on local resources among the 8 groups of stable cities
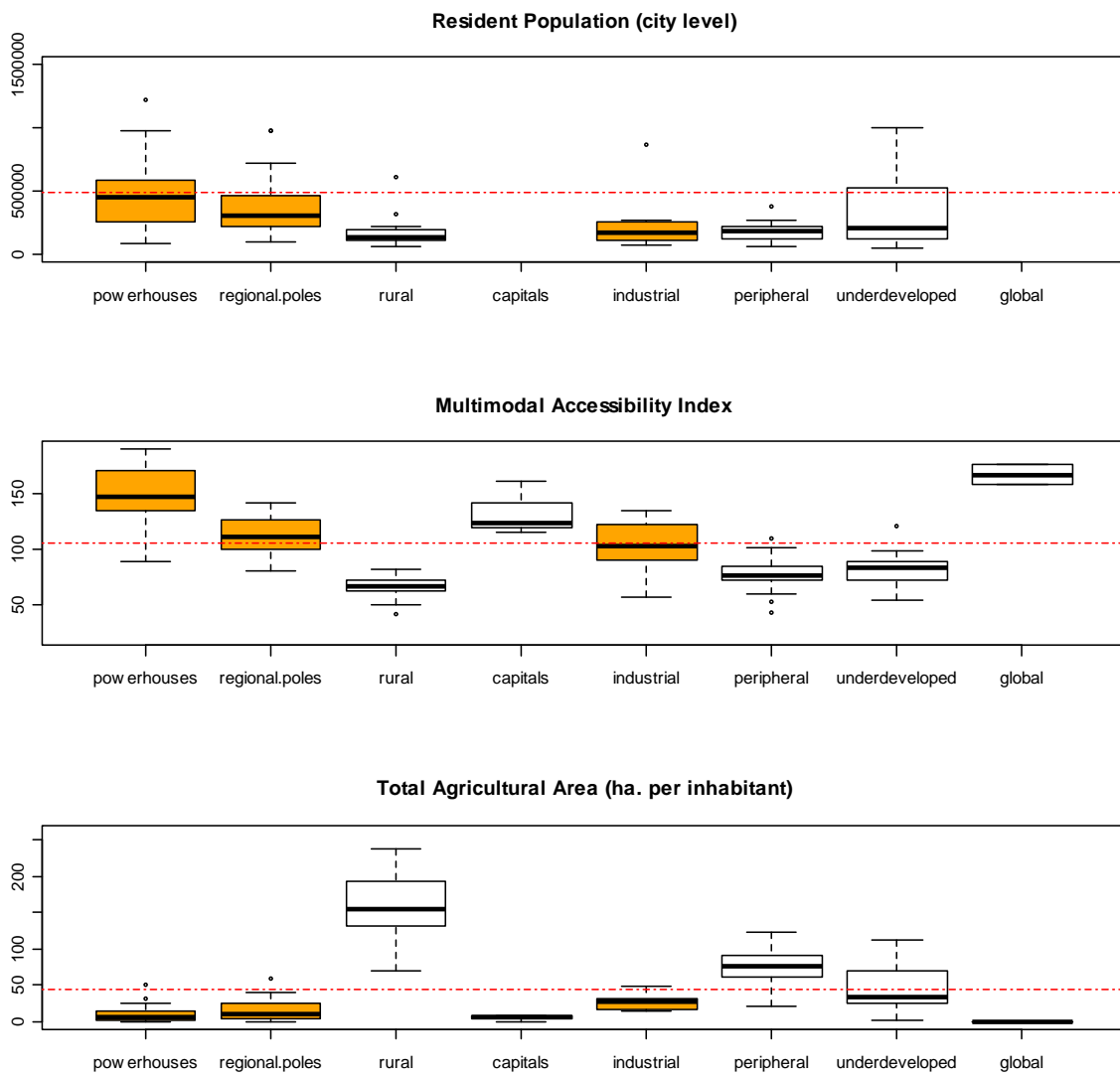
Source: personal elaboration on Urban Audit-Eurostat (2010); REGIO-Eurostat (2010) and © ESPON Database, (2006).

Figure 5 – Cities that are exploiting local resources in an unsustainable way: stable powerhouses, stable regional poles and stable industrial cities
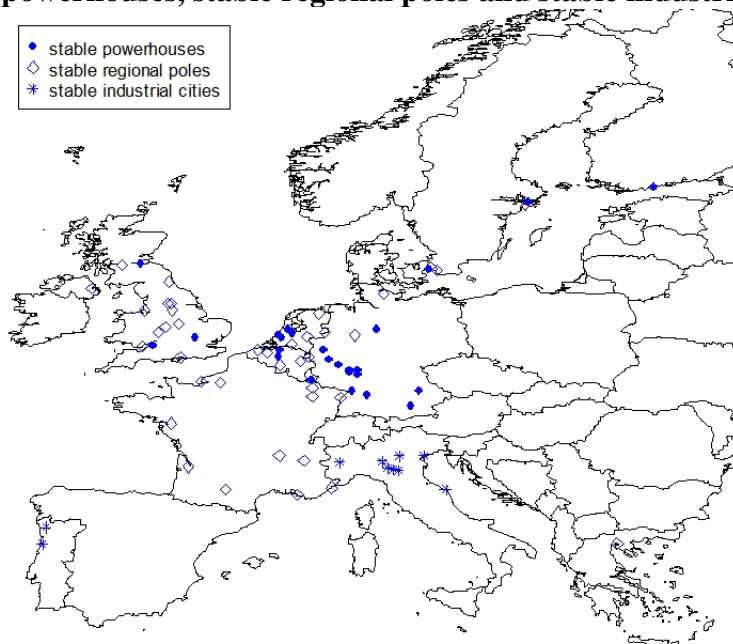
Source: personal elaboration on Urban Audit-Eurostat (2010); REGIO-Eurostat (2010) and © ESPON Database, (2006).

4   Structural and economic drivers of potential for polycentric integration

The challenges European medium-sized cities are facing in terms of sustainability are now clear. Unfortunately, solutions are less easy to find. We may recognize a 'market failure' in the way those cities are growing: their growth mechanism seems to be unsustainable in the long run. So we can conclude that institutions (at both national and local level) should be concerned. But, like markets, institutions may fail. So it is hard to identify which policies can best foster sustainability in medium-sized cities and the surrounding regions. Some suggestions emerge from an observation of these cities' geographic distribution (see again figure 5).

As already said, in recent years, polycentrism has been seen to be a possible strategy for governing networks of medium-sized cities. Although precise definitions of the concept may vary, polycentrism can foster urban sustainability through more integrated governance of wider regions. In other words, polycentrism is a way of acknowledging multiscalarity in European urban phenomena. In that sense, a potential for polycentric integration exists right across the continent of Europe (ESPON, 2005). In particular, policies reinforcing polycentrism are intended to promote synergies between cities (Meijers, 2005), both limiting the exploitation of land and leading to more rational allocation of population and industrial activities across a region.

Here we can adopt polycentrism as a working hypothesis functional to the theme of the exploitation of resources in a multi-scalar perspective. By analysing the morphological features of the European urban system, we can check whether those cities that share the heavy exploitation of resources also share a higher potential for polycentric integration. We do not study the implications of polycentric policies on sustainability[15], but attempt to identify the main drivers of polycentrism in terms of cities' economic and structural features.

An analysis of this kind is not simple. Generally, polycentrism is analysed through single case studies (Bailey *et al.*, 2001; Meijers *et al.*, 2003; Meijers, 2005; Meijers, 2008; Cowell, 2010). A focus on a single area makes it possible to use a large amount of information about the geographic structure of employment and settlements (see Riguelle *et al.*, 2007) and the policies adopted. When a comparative approach is followed (see, for example, ESPON, 2005), some difficulties emerge in terms of both choice of indicators and the right scale of analysis[16]. In this section, we adopt an approach to polycentricism fundamentally based on two related concepts developed by ESPON (2005): the concepts of FUA and PUSH. The approach leads us to identify PIAs (potential polycentric integration areas) by considering cities with overlapping PUSH areas as nodes of inter-urban networks (see section 2). This approach can be linked with our previous analysis based on core city data, reinforcing our multi-scalar approach, as PIAs generally cover many NUTS-3 regions.

To study the drivers of polycentrism, we need to calculate a degree of potential polycentric integration for each city in the sample. Different measurements can be used. In our analysis, after having linked each city to its PIA (either as "PIA main node" or as "PIA secondary node"), we then compute the *gain in demographic mass*, or the increase in population that each city experiences as a consequence of being part of a polycentric integrated area[17]. For cities that do not belong to a PIA, we consider the increase in population due to the existence of the PUSH area (i.e., the 45 minute isochrones around each FUA). This gain in demographic mass can be considered a good proxy for each city's polycentric integration potential. The control variables are the number of FUAs in each PIA[18] (for cities not belonging to any PIA, this indicator is equal to one); and a qualitative variable, showing the city's status with regard to PIAs (that is, main or secondary node).

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[15] That is, if they really can abate the degree of exploitation of natural resources or the levels of pollution.

[16] ESPON (2005) shows how different results are obtained when different measurements of polycentrism are adopted across European regions. Moreover, the analysis of polycentrism at the national level leads to distorted results.

[17] From a methodological point of view, we take the logarithm of the ratio between PIA population and core city population and use it to correct for the skew in the ratio's density distribution. ESPON (2005) suggests two different perspectives for assessing this change in demographic mass: i) looking at the percentage change by comparing the population of each PUSH area and that of the entire PIA; ii) looking at how this change affects a city's position in the European urban hierarchy.

[18] A PIA of 27 *FUAs* (i.e., the Milan *PIA*) is considered much more polycentric than a *PIA* of only 3 *FUAs* (i.e., the PIA of Paris), even if their total populations are almost the same (in this case, 12.86 million and 11.36 million inhabitants respectively).

In the regression analysis which follows (table 4), we use gain in demographic mass as dependant variable. In model 1, the only regressors used are urban structural features (LAU-2 level). By controlling for the population logarithm, model 1 shows that all variables but proportion of graduates explain the gain in demographic mass. Potential for polycentrism is positively related to accessibility: as already observed, the most polycentric areas are the central regions of the continent. Moreover, the presence of a strong network of infrastructures in a region (not only a road network, but also railway systems and scheduled air services) has a positive impact on its degree of potential polycentric integration. The interpretation of the negative sign for per capita income is not so clear. It is affected by the fact that monocentric capitals are the wealthiest cities in Europe. The significant positive relationship between gain in demographic mass and proportion of employment in manufacturing is interesting, although the relationship is no longer significant if we do not control for the city population logarithm. If industrial cities have a higher gain in demographic mass, we can suppose that the largest PIAs cover the most industrialised areas and cities in Europe. In contrast, capital cities, where the proportion of employment in manufacturing is generally lower as a proportion of total employment, are typically monocentric. Finally, as expected, we observe a significant negative relationship between potential for polycentrism and agricultural area per inhabitant: rural cities are generally isolated and not included in polycentric networks.

In model 2, we control for the number of FUAs in each PIA and the city's status with regard to PIAs. We do not observe significant changes in the signs and coefficients of the independent variables. As expected, the relationship between gain in demographic mass and number of FUAs is significant and positive (the former increases by 5.5% for each additional FUA in the same PIA). In addition, cities that are secondary nodes, *ceteris paribus*, show a significantly higher gain in demographic mass compared to the PIA's main node. On the other hand, the gain in demographic deriving from a PUSH (for cities not belonging to a PIA) is significantly smaller.

In model 3, we also control for a dummy that shows whether a city belongs to the clusters with high exploitation of local resources. The relationship is positive, but only at the 0.10 level of significance. This is an important result. It means that the previous classification (see again section 3) identifies cities with not only a higher degree of exploitation of local resources, but also a higher degree of potential polycentric integration[19]. So, geographically speaking, the two phenomena are well related: the potential for polycentrism really lies where it is needed. Medium-sized cities with heavy exploitation of environmental and human resources show the highest potential for polycentric integration of all European cities.

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[19] If this dummy is split into four different indicators (i.e. stable powerhouses, stable regional poles, stable industrial cities and other cities) the differences in gain in demographic mass are no longer significant.

Table 4 – Multiple regression analysis of the gain in demographic mass (population ratio logarithm)

	Model 1	Model 2	Model 3
Intercept	1.125e+01 *** 8.468e-01	9.732e+00 *** 6.598e-01	9.499e+00 *** 6.656e-01
Logarithm of Population	-9.251e-01 *** 7.694e-02	-7.351e-01 *** 5.963e-02	-7.156e-01 *** 6.001e-02
Per capita GDP	-2.852e-05 *** 6.807e-06	-1.067e-05 * 4.917e-06)	-1.246e-05 * 4.966e-06
Unemployment Rate	-3.103e-02 * 1.249e-02	-1.900e-02 * 8.804e-03	-1.843e-02 * 8.739e-03
Employment in industrial sectors	2.937e-02 ** 9.343e-03	2.060e-02 ** 6.583e-03	2.015e-02 ** 6.535e-03
Graduates	1.020e-02 1.156e-02	-1.103e-03 8.119e-03	-3.916e-03 8.186e-03
Accessibility	2.977e-02 *** 2.544e-03	1.444e-02 *** 2.170e-03	1.450e-02 *** 2.153e-03
Agricultural Area per inhabitant	-6.056e-03 *** 1.453e-03	-2.746e-03 * 1.068e-03	-2.107e-03 . 1.111e-03
TypeNode: No PIA		-6.104e-01 *** 1.098e-01	-5.921e-01 *** 1.093e-01
TypeNode: secondary		4.227e-01 *** 1.081e-01	4.171e-01 *** 1.072e-01
High Pressure cities: Yes			1.682e-01 . 8.723e-02
Number of FUAs		5.522e-02 *** 7.488e-03	5.475e-02 *** 7.433e-03
Adjusted R^2	0.7033	0.8563	0.8586
F-Statistics	61.95 on 7 and 173 DF p-value: <2.2e-16	108.3 on 10 and 170 DF p-value: <2.2e-16	100.3 on 11 and 169 DF p-value: <2.2e-16
N	181	181	181

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Notes: All variables refer to core city level (i.e., LAU-2 level). Accessibility (that is, multimodal accessibility index) and Agricultural area per inhabitant refer to NUTS-3 regions. "High Pressure cities: yes" is a dummy that shows whether a city belongs to the stable "powerhouses", stable "regional poles" or stable "industrial cities" category. "Type Node: No PIA" and "Type of Node: secondary" are indicators showing which kind of node a city is in the PIA it belongs to. The omitted indicator is "PIA main node".

Source: personal elaboration

As we cannot collect detailed data at the infra-municipal level for a large number of European cities, we can say nothing more about the relationship between polycentrism, urban sprawl and exploitation of resources. However, our findings are still quite interesting, especially as an exploratory analysis. The hypothesis of polycentrism as a possible form of multi-scalar governance appears strong, even though we only analyse it in potential terms[20]. At the same time, further steps in the research should be specifically targeted towards a deeper analysis of a small number of polycentric regions. Only through direct exchange between researchers, urban planners and local policy-makers is it possible to study and compare the policies that have been adopted to strengthen the idea of polycentrism in a given area.

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[20] We only look at the morphological features of cities that may lead to polycentric integration. We do not study why policies have been adopted to create PURs.

5   Conclusions

The theme of the exploitation and reproduction of resources plays a key role in the sustainability of medium-sized urban areas. In analysing it, cities have to be considered as processes which produce and reproduce both human activities and resources: it is therefore clear that a problem of the scale of analysis emerges. In particular, core cities (that is administrative cities) appear to be too small to allow the capture of economic and environmental phenomena. Moving on from administrative cities, we first identified different types of urban areas on the basis of economic and structural data. Then we turned to NUTS-3 regions to test the results obtained through a multi-scalar approach: similar clusters are returned whether urban data or regional data are used (that is, using LAU-2 and NUTS-3 level data respectively). An initial conclusion can be drawn: in Europe, urban dynamics generally also involve the suburban and rural areas around cities. At the same time, if cities are not isolated, urban planning must involve wider areas which generally cross administrative boundaries. Moreover, this is true for medium-sized cities even though they generally do not enforce multi-scalar urban plans.

Moving on from the results of cluster analysis, we analyse sustainable development across cities and NUTS-3 regions. Although we only used structural data about cities, the clusters obtained also differ in terms of the degree of exploitation of local resources. In particular, industrial cities, powerhouses and regional poles share a common feature: a way of exploiting natural resources that is no longer sustainable (remember the excess urbanization, the absence of rural areas and the mass of infrastructures).

But the most surprising finding is that these cities share another important feature: they have potential for polycentric integration. Although polycentrism has to be considered as the outcome of institutional activity (i.e., a form of governance of networks of neighbouring cities), we tested its main economic and structural drivers (and this is why we talk about potential for polycentric integration). Accessibility, the absence of rural areas and the presence of manufacturing activities are the main features that cities with the highest potential for polycentric integration share.

So, after identifying a clear 'geography of exploitation' of resources, we also highlighted a strong link between problems (i.e., heavy exploitation of resources) and possible solutions, as suggested in the recent debate about polycentrism.

However, before such optimistic conclusions are drawn, further aspects should be analysed. First, it should be remembered that the existence of potential for polycentric integration does not assure the actual development of polycentric networks of cities. The choices made by policy-makers (both at local and national level) are important for the achievement of specific results. At the same time, we also know that institutional activity may fail. So, in future developments, a few case studies focusing on the best polycentric policies across Europe will be of great interest and allow their effects on environmental issues and the

reproduction of resources in urban regions to be studied. Secondly, future analysis should also include the disruptive effects of the current economic crisis on European cities. In particular, it will be interesting to test whether polycentric urban regions can obtain better results than monocentric ones in managing the rise in unemployment, possible social unrest and the lack of funds for public policies.

Appendix – Cities and indicators

The Urban Audit – Eurostat Database (2010) contains information about more than 300 variables (referring to nine domains, from demography and the economy to culture and recreation) for 321 cities in the EU-27 Member States; 26 Turkish cities; 6 Norwegian cities and 4 Swiss cities (European Union, 2004). All data refer to core cities, in accordance with political and administrative boundaries. Local Administrative Unit level 2 (LAU-2) is generally used. In France, the concepts of *Communauté d'agglomération* or *Communauté urbaine* are used; in Portugal, UK and Ireland, LAU level 1 units are used (European Union, 2004; European Union, 2010).

As data coverage is rather poor, our analysis is limited to cities in Western European Countries (i.e. EU-15 Member States). In keeping with this choice, cities belonging to Germany's Eastern Länder are excluded from the sample. Cities belonging to French Overseas Departments, to the Canary Islands (ES) and to the Azores Islands and Madeira (PT) are also excluded from our sample. On the other hand, to strengthen our focus on Northern Italy, information for Parma, Reggio Emilia and Modena (IT) has been reconstructed. Our final sample includes 181 cities.

Information for the NUTS-3 regions around these cities has also been collected. Note that:

- The cities of Le Havre (FR012C) and Rouen (FR015C) belong to the same NUTS-3 region, the French *department* of Seine-Maritime (FR232);
- NUTS-3 regions are too small to contain a functional area surrounding London and Paris, so we consider a NUTS-2 region for Paris (Île de France - FR10) and a NUTS-1 region for London (London – UKI).
- In Germany, many NUTS-3 regions correspond to *stadtkreis* (or to *Kreisfreie Stadt*), the administrative units used to define core cities in the Urban Audit. From a methodological point of view, even if core cities and NUTS-3 regions correspond, we use data from different databases: the Urban Audit data for core cities and REGIO-Eurostat data for NUTS-3 regions.

In terms of the variables adopted, table A.1 shows the seven variables that are used in cluster analysis. Five indicators are available both at core city level (LAU-2) and at NUTS-3 level. For the core city level, the statistical source is the Urban Audit Database; for the NUTS-3 level, the statistical source is the REGIO-Eurostat Database (2010). Conversely, *multimodal accessibility index* (source: © ESPON Database, 2006) and *total agricultural area per inhabitant* (source: REGIO-Eurostat, 2010) are only available at the NUTS-3 level. All data refer to 2001.

Table A.1 also shows the variables adopted to describe the polycentric features of European cities. For these indicators the source is ESPON Project 1.1.1 (2005).

Table A.1 – Description of indicators

Names of indicators	Description	Core cities code	Nuts-3 regions code
Total Resident Population	All persons recorded as resident in households in an area, even if they were present elsewhere on Census night, plus residents in communal establishments who were present in the establishment on Census night. This will include all persons, national or foreign, who are permanently settled (i.e. resident for one year or more) in the (urban) area. In some countries (e.g. Ireland), the Census counts the *de facto* population, i.e. the population present on Census night but not necessarily registered (*de jure*).	Popul_C	Popul_N
GDP per head of resident population	$$\frac{Total\ GDP}{Total\ population\ (all\ ages,\ working\ or\ not)}$$ Total Gross Domestic Product is the sum of the gross value-added at basic prices of all resident producers, plus all taxes less subsidies on products. The source is Eurostat, CODED, SNA95. For sub-national levels, the income approach is used.	GDPp.c_C	GDPp.c_N
Unemployment Rate	$$\frac{Unemployed\ person}{Total\ economically\ active\ population}$$ In accordance with ILO and the Community Labour Force Survey definition, unemployed persons comprise all resident persons above 15 and under 75 who, during the reference period, are: i) without work, i.e. neither have a job nor are not at work (for one hour or more) in paid employment or self employment; ii) available for work; iii) actively seeking work.	Unem_C	Unem_N
Proportion of employment in industries C-E, NACE Rev.1	$$\frac{Employment\ in:mining\ and\ quarrying\ +\ manufacturing\ +\ electricity,\ gas\ and\ water\ supply}{Total\ employment}$$ NACE Rev. 1 is a Statistical Classification of Economic Activities from Eurostat. Industries C-E refer to typical manufacturing employment (mining and quarrying; manufacturing; electricity, gas and water supply). Employment in the construction industry is not included in the indicator.	Employm C.E_C	Employm C.E_N
Proportion of population qualified at ISCED levels 5 and 6:	$$\frac{Population\ qualified\ at\ ISCED\ level\ 5-6}{Total\ resident\ population}$$ There are 6 different levels of education in the International Standard Classification for Education (ISCED). Level 5 corresponds to the first stage of tertiary education (not leading directly to an advanced research qualification), including programmes that lead to the award of a first or second university degree. Level 6 is the second stage of tertiary education (e.g. PhDs, etc).	Isced5.6_C	Isced5.6_N
Multimodal accessibility index	The index corresponds to the Potential Accessibility Indicators proposed by the Study Programme on European Spatial Planning (Eskelinnen et al., 2002). Potential accessibility is based on the assumption that the attraction of a destination increases with size, and declines with distance, travel time or cost. So, accessibility is a construct of two functions, one representing the activities or opportunities to be reached and one representing the effort, time, distance or cost needed to reach them: $$A_i = \Sigma\ g(W_j)\ f(c_{ij}),$$ Where, *Ai* is the accessibility of area i, W_j is the activity W to be reached in area j, c_{ij} is the generalized cost of reaching area j from area i. Functions $g(W_{ij})$ and $f(c_{ij})$ are called *activity functions* and *impedance functions* respectively and they are weights to each other. The indicator is standardized to the average accessibility of the ESPON space (that is EU-15 + 12 Candidate Countries). In greater detail, the multimodal accessibility index is calculated using road accessibility, rail accessibility and air accessibility. Data source for this variable is © ESPON Database, 2006.	Access_C = Access_N	

Total Agricultural Area per inhabitant	$$\frac{\textit{Total agricultural area (ha.)}}{\textit{Total resident population}}$$ The total agricultural area includes arable land (D), permanent pasture (E), meadows (F), permanent crops (G) and woodlands (H). It is measured in ha. For German regions, total agricultural area is only available for NUTS-2 regions (so it is divided by total population in NUTS-2 regions).		TotalAgr.ab_C = TotalAgr.ab_N
Demographic mass gaining	*Cities belonging to PIAs*	$$Ln\left(\frac{\textit{PIA population}}{\textit{core city population}}\right)$$	
	Cities not belonging to PIAs	$$Ln\left(\frac{\textit{PUSH population}}{\textit{core city population}}\right)$$	
No. of FUAs in PIA	*Number of FUA belonging to the same PIA* For cities not belonging to any PIAs = 1.		Number of FUAs
Status of the city with regard to PIAs	Three possible statuses: i) *PIA Main Node;* ii) *PIA Secondary Node;* iii) *Node not belonging to any PIAs*		Omitted TypeNode: secondary TypeNode: No PIA

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