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Functional Polycentrism in Portugal: an evaluation

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Functional Polycentrism in Portugal: an evaluation

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Abstract

This paper aims at develop an evaluation of the functional polycentrism of Portuguese municipalities. For that purpose, we develop a critical assessment of the concept of polycentrism and functional polycentrism whose assumptions guide most of the policies of regional planning, and present the main methodologies for its evaluation. We then proceed with the evaluation of polycentricism in Portugal, by using the Social Network Analysis and the Cluster Analysis. The study considers the variable ‘commuting flows home-to-work’ and the results suggest that, from 1991 to 2001, the Portuguese urban system presents a network of commuting denser, less centralized, more dispersed and more clustered.

Keywords: polycentrism; cities; social network analysis; cluster analysis.

JEL Codes: R12, L14, C19

1. Introduction

The topic of polycentrism have gained importance in recent times and became established as a normative concept in the European agenda of spatial planning (Faludi, 2006; Eskelinen and Fritsch, 2009). The EU members recently adopted the *Territorial Agenda of the European Union* (EU, 2007), which assumes that, at the present, polycentrism is much seen as cohesion than competition among locals (Meijers, 2008). The scenario of a polycentric European territory aims at explain the economic and social cohesion and reduce the disparities in the development of European regions (EDEC, 1999). The creation

of cooperation networks between peripheral areas, and especially among metropolitan ones, is the way for the construction of polycentric regions (EDEC, 1999).

However, the concept of polycentrism is not consensus, yet it doesn't exist a clear definition, with a theoretical and empirical robustness (Davoudi, 2003), and therefore it requires a review and clarification of the concept.

In Portugal, although there are some studies on the urban system (e.g. Albergaria, 1999; Ferrão and Sá Marques, 2003; Delgado and Godinho, 2006), the evaluation of the polycentrism and its evolution are absent in the literature.

Thus, a target directly linked to this work is to review the concept of polycentrism and functional polycentrism, which are concepts that recently gained importance to denote not only the morphology of urban areas (size, location and urban hierarchy), but also the functional specialization (networks, flows and cooperation) of multiple urban areas or regions in global (Davoudi, 2003). Secondly, this paper also makes a systematization of main research methodologies of the empirical evaluation of polycentrism that exist in literature. Finally, it presents an attempt to assess the configuration of the polycentric urban system in Portugal, by using the techniques based on Social Network Analysis (SNA) and Cluster Analysis. Particularly, it analyses the main measures of network structure and centrality used in social networks literature, and discusses the results obtained in the hierarchical clustering methodology.

Following this Introduction, Section 2 discusses the concepts of polycentrism and functional polycentrism, and the main lines of empirical investigation are presented in Section 3. Section 4 presents the methodology and results of the evaluation of polycentrism in Portugal. In the final section, a summary of the main conclusions and some lines for future research are presented.

2. Policentrism and functional policentrism: a critical review

Polycentrism arises as a result of the existence of a set of integrated urban centers in the urban region, with high potential of attractiveness, competitiveness and internationalization (Parr, 2004). It embodies the idea that a metropolitan urban area might generate a structure consisting of multinuclear peripheral urban areas (Dieleman and Faludi, 1998), with which the 'central city' establishes a series of complementary relations (Ascher, 1998), even though the economic relations established by these cities might be independent of the central city (Garreau, 1991). This multinuclear scheme is due, in large measure, to the

extension of the original metropolitan centers into the spread of job centers and equipments (Richardson, 1988). These sub-centers play an important economic dynamic because they turn into focal points of work, commerce and entertainment, which result in a pattern of urban concentration in a smaller scale than the central city (Castells, 1997).

This means that the urban growth promoted the formation of peripheral urban areas as part of the territorial restructuring that was carried out in cities in the context of economic globalization (Castells, 1997), which lead the large economic groups to assert their preference of location in large cities - metropolis - for the implementation their central activities (Blanco, 1996), namely financial services (Sassen, 1998).

More recently, the European Spatial Planning Observation Network (ESPON) claims that two complementary aspects are linked to the concept of polycentrism: the morphology of space (number and hierarchy of cities) and the functional relationships between urban areas (network, flows, cooperation) (ESPON, 2005). The concept of polycentrism in Europe is then based on the functional specialization of the urban areas and not on their size or dimension, being referred as an alternative model of metropolitan concentration around major cities (namely, the so-called 'Pentagon' London, Paris, Hamburg, Milan and Munich, which are the core of the EU space that concentrates abilities, skills and wealth) (CEC - ESDP, 1999). The polycentrism is then the opposite of monocentrism (concentration) or urban sprawl (continuous space and non-organized).

The functional polycentrism, or polynuclear urban spaces, is then seen as a complex system of urban centers in which the centralities occur in various parts of the territory and tend to have a functional and specialized content. It refers to networks of urban centers among which there is an increasing interdependence, mobility, connectivity and complementarity (Dematteis, 1990, 1991). The relationship is increasingly based on networks of complementarities rooted on the local specialization or in the agglomeration of specialized and interdependent functions (Camagni and Salone, 1993). It refers to urban areas that assume a coordinating role and centers of knowledge dissemination (Trullén and Boix, 2001).

However, the polycentric approach should not be divorced from the spatial organization of territories, that is, the different dimensions of spaces in terms of area, population density, employment, commuting, etc. (Parr, 2004), and also from the fact that the regional economy growth is not comparable across different spatial structures (Meijers et al., 2007). The diversity of interpretations underlying the concept of polycentrism at different spatial

scales, result, for some authors, from the complexity of the structure of cities (Davoudi, 2003). Cities fall increasingly in a supra-national context, and relations of complementarity and synergy between cities at the same level, became more important than the relationships between each city and towns in its area of influence (Mérenne-Schoumaker, 1996).

The polycentric model of Camagni (1992) of decentralized concentration, allows, on one hand, to maintain the competitive advantages of urban centers and, on the other hand, to alleviate the disadvantages inherent to large urban areas through the strength of the relations intra-region and reduction of the dependence of the central city. However, it should beware of situations of detachment of the main urban areas, namely, the formation of archipelagos of urban centers that are integrated in the global network and surrounded by disconnected areas (Ferrão, 1992).

3. Polycentrism: main lines of empirical research

The concept of polycentrism is not consensual, while there isn't a clear and robust definition of polycentrism (Davoudi, 2003). Polycentrism can be applied to a local scale (Roberts et al., 1999), a regional scale (Hall and Pain, 2006; Parr, 2004; Meijers, 2007), a national level (Waterhout et al., 2005) or at the European level (CEC - ESDP, 1999), with different interpretations of polycentrism for different spatial levels (Kloosterman and Musterd, 2001; Davoudi, 2003; Hague and Kirk, 2003; Eskelinen and Fritsch, 2009). Even showing, when comparing with monocentrism and from the economic point of view, more advantages than disadvantages (Parr, 2004), according to recent studies (Kloosterman and Musterd, 2001; Bailey and Turock, 2001; Davoudi, 2003; Meijers and Romein, 2003; Parr, 2004; Faludi, 2006; Meijers et al., 2007), the operationalization and application of this concept is complex and extremely demanding in terms of its implementation (Carmo, 2008).

Among other obstacles, it is referred the questions related to identify, i.e., the recognition of the populations that they belong to the same region (Kloosterman and Musterd, 2001); also, its non-applicability to territories which have a morphology in the form the archipelago; in addition, the problems related to the coordination of policies between different administrative levels (Bailey and Turock, 2001; Davoudi, 2003; Meijers and Romein, 2003). On the other hand, the polycentric approach cannot be dissociated from the new trends in spatial organization (Parr, 2004), i.e., the need to combine aspects of social and economic transformation - models of the New Urban Economics - with aspects of

location, which become paradigms of spatial organization - the New Economic Geography models (Meijers and Sandberg, 2008).

Thus, the emergence of new and different perspectives of polycentrism encouraged the application of methods that are born outside the context of the theoretical origin of the concept (Green, 2007; Meijers, 2008).

There is already a significant applied research to the study of polycentric urban regions in the literature. The analysis and assessment of these works reinforces the idea that until the 90s, most studies focus on the impact of subcenters on the rent and intensity of land use (McDonald, 1987), and on the location of employment subcenters as a main characteristic of functional polycentrism, mainly in the United States (McDonald, 1987; Giuliano and Small, 1991; Waddell and Vibbooti, 1993, McDonald and Prather, 1991, Gordon and Richardson, 1996, McMillen and McDonald, 1998; McMillen and Smith, 2003; Modarres, 2003) and Europe (Muñiz et al., 2003; Trullén and Boix, 2003; Baumont et al., 2004; Guillain et al., 2004). The city of Los Angeles is considered as the prototype of the metropolitan regions and is taken as a reference for studies on metropolitan polycentric structures (Giuliano and Small, 1991, Gordon and Richardson, 1996), in which the pattern of a compact city gives rise to a polycentric and dispersed city, driven by market forces (Hoyt, 1939; Gordon and Richardson, 1996).

Additionally, it is possible to observe that the most common variables used to study polycentric regions are the employment and business trips because they allow the identification of sub-centers (Giuliano and Small, 1991; McDonald and Prather, 1991). The finding that not all sub-centers result from the spread of employment and population emphasized the need to define alternative methodologies to measure the polycentrism (Giuliano and Small, 1991; Gordon and Richardson, 1996; Muñiz et al., 2003, McMillen and Smith, 2003). In addition to the initial indicators, researchers added functions and services provided by a specific area in the provision of resources (Advanced Production Services), communications and others (Shin and Timberlake, 2000; Trullén and Boix, 2001; Davoudi, 2003; McMillen and Smith, 2003; Meijers, 2006, 2008; Meijers et al. 2007; Green, 2007; Meijers and Sandberg, 2008; Zhendong, 2008).

The methods most commonly used and applied in evaluating the polycentrism are rooted in techniques based on Geographic Information Systems - GIS (ESPON, 2005; Hoyler et al., 2008b) and spatial econometric techniques, using, in particular, the estimation of not linear functions (McDonald and Prather, 1991; Meijers et al. 2007; Meijers and Sandandberg, 2008), the method of ordinary least squares (Trullén and Boix, 2001) or Local Weighted

Regression (McMillen and McDonald, 1998; McMillen and Smith, 2003). Descriptive statistics are also used, making use of indicators such as Gini coefficients, coefficients of localization and specialization (Gordon and Richardson, 1996; Trullén and Boix, 2003; Meijers, 2008), as well as the Moran index (Baumont et al., 2004; Guillain et al., 2004) and the Local Indicators of Spatial Association (Guillain et al., 2004). Particular relevance are even techniques of data analysis such as ANOVA and cluster analysis (Modarres, 2003; Trullén and Boix, 2003; Baumont et al., 2004). Finally, a particular reference to the networks analysis, used by a relevant set of recent studies (Shin and Timberlake, 2000; Green, 2007; Patuelli et al., 2007; Hoyler et al., 2008a).

4. Evaluating the policentrism in Portugal

The main objective of this study is to assess the configuration of the Portuguese urban system, focusing on the functional dimension of polycentrism and recurring to the Social Network Analysis (SNA) and the Cluster Analysis.

In particular, we intend to investigate to what extent the changes in the last two censuses, 1991 and 2001, reflect the existence of different functional trajectories, i.e., tendencies of functional convergence or divergence in the flows home-to-work.

A polycentric urban system requires that the assumptions of morphology (hierarchy, size, location and connectivity) are associated with the ability of cities to relate functionally to each other (ESPON, 2005). Additionally, we may observe that the European polycentric urban systems have Christallian origin, which are, in most cases, the result of the functional integration of cities through the labor markets (Champion, 2001). For this reason, this work will focus on the functional dimension of polycentric.

With the aim of evaluating the functional polycentrism in Portugal, the indicator under consideration is the commuting of the employed population by residence and workplace, which is available at the National Statistics Institute (INE), namely in Censuses 1991 and 2001 (INE, 1991, 2001). This information is a prime source for the analysis of functional networks between municipalities and / or regions, as the commuting results of the non-coincidence between the place of residence and place of work or study (INE and MOPHTH, 2003).

It should be noted the difficulty in obtaining other indicators to account for the assessing the functional polycentrism in Portugal, such as business trips, business emails, traffic,

provision of advanced producer services), which are not available for the Portuguese case, or, when they exist, they do not allow the characterization of the Portuguese urban system. With the aim of assessing the polycentrism in Portugal mainland in 1991 and 2001, and after a brief descriptive analysis of the commuting matrices, two alternative and complementary methodologies are used. At first, the Social Network Analysis (SNA) is used, which allows the evaluation and parameterization of the network flows between Portuguese municipalities. In a second step, the Cluster Analysis is employed, which allows grouping the municipalities based on their di (similarity) or relative distance.

4.1. Commuting Matrices

The analysis considers, in 1991 and 2001, respectively, 275 and 278¹ Portuguese municipalities (mainland)² and the commuting home-to-work, by municipality of origin and destination. Therefore, in 1991 the network consists of 275 nodes, and in 2001 it comprises 278 nodes, while these nodes are functionally related in terms of commuting flows, i.e., the system is composed of two functional networks: an in-commuting and an out-commuting network.³

The main indicators of the commuting matrices 1991 and 2001 are presented in the following table (Table 1):

Table 1 – Key indicators of the commuting matrices: 1991, 2001

<i>Commuting Indicators</i>	1991	2001
	Nº	Nº
Nodes or vertices (g) (municipalities)	275	278
Nodal degree (actual) (L)	898 084	1 334 000
Potential nodal degree (L max.)	3 744 656	4 384 114
Average nodal degree (L aver.)	3 265,8	4 798,6
Density (V)	0,2398	0,3042
Standard deviation of in-commuting	18 240,56	23 709,47
Standard deviation of out-commuting	8 256,45	10 643,38

Source: Own computations, from INE (1991, 2001).

¹ In 1998, the municipalities of Vizela, Trofa and Odivelas were created.

² Given that the objective of this work is the study and measure of the functional polycentrism, it has been excluded the island of Azores and Madeira.

³ The commuting flows intra-municipalities have been excluded.

The analysis of the nodal degree or flows between nodes might identify the number of links that focus on a node (L) in terms of in-commuting and out-commuting flows, revealing that the nodal degree increased from 1991 and 2001.

Following the methodology proposed by Green (2007), the network density is identified as the ratio between the total connections (L) and total potential links (L max.), and may take the minimum value of 0 (no density) and maximum value of 1 (maximum density of the network). The Portuguese urban system is then characterized by an increased commuting density, since, between 1991 and 2001, the network density increased from 0.2398 to 0.3042, indicating an intensification of commuting flows in the period under review.

By studying the pattern of in and out commuting, and in particular, the standard deviation of flows, it appears that the standard deviation increased between 1991 and 2001, being higher in terms of in-commuting.

The analysis and comparison of the commuting matrices between 1991 and 2001, reveals the increasing importance of intra-municipal movements (7.1%) and namely the inter-municipal movements (48.5%). Additionally, despite the general increase in the movements between the municipalities that make up the Portuguese urban system, it is observed the lack of functional interaction between some municipalities, or with insignificant commuting values. Therefore, the Portuguese urban system presents, from 1991 to 2001 and in terms of commuting flows, functional interaction with a scattered distribution pattern or with few employment poles.

4.2. Social Network Analysis

Social Network Analysis (SNA) provides metrics and tools to study the social networks, which derives from quantitative data that evidences the functional interaction between agents. Based on the Graph Theory - a graphic and formal representation of networks – it will be made a representation of the results in terms of flows of interactions (connections) among nodes, without any reference to the orientation, position or distance between nodes (De Nooy et al., 2005).

In this methodology, the nodes or vertices correspond to the municipalities, while the arcs represent the connections between nodes (De Nooy *et al.*, 2005).

Information is presented in the form of arrays of information, also called socio-matrices. Thus, the commuting matrices generated for 1991 and 2001, show us the values of indegree (number of links that have this nodes as destination, also called nodal degree of

entry or in-commuting) and the values of outdegree (number of links that have this nodes as origin, also called nodal degree of outflow or out-commuting).

The application of SNA allows us to the evaluate a network (Hanneman, 2001; Scott, 2000; Wasserman and Faust, 1994; De Nooy et al., 2005), being the most frequent measures of structure and network centrality the ones listed below, calculated by using the software Pajek (Table 2):

Table 2 – Network parameters of commuting: 1991, 2001

<i>Commuting parameters</i>	1991	2001
Indegree Closeness Centralization	a)	0.40231
Outdegree Closeness Centralization	a)	0.24786
All Closeness Centralization	a)	0.70851
Betweenness Centralization	0.11603	0.03385
Indegree Centralization	0.80043	0.69649
Outdegree Centralization	0.52507	0.50809
All Degree Centralization	0.66515	0.59356
Diameter	3	3
Clustering Coefficient	0.44167	0.51293

Source: Own computations, from INE (1991, 2001).

a) values not possible to compute due to poor network connectivity of commuting, 1991

The analysis of the Table 2 allows us to characterize the networks of commuting in 1991 and 2001.

In terms of global centrality, it appears that in 2001, there is a greater proximity of the nodes (assessed by the *closeness centralization*⁴) in terms of inflows (indegree) than in terms of outflows (outdegree), i.e., the network of in-commuting has increased the degree of closeness more than the network of out-commuting. It appears that, in terms of degree of intermediation (*betweenness centralization*⁵) of one node over the other nodes, that is higher in 1991 than in 2001, indicating a decrease of the commuting flows in intermediate

⁴ The *closeness centralization* is a measure of the overall closeness or distance of a node in relation to the other nodes.

⁵ The *betweenness centralization* is a measure of the global centrality that is calculated based on the intermediation of a node with other nodes not adjacent and not directly connected with.

nodes or an increase in these flows in larger nodes or else a preference for locating in nodes with fewer difficulties of commuting, from 1991 to 2001.

In terms of the degree centralization of a node (assessed by the *degree centralization*⁶), it is higher in 1991 than in 2001, both in terms of inflows (indegree) and in terms of outflows (outdegree), that is, there is a higher nodal centrality in 1991 compared to 2001. Despite the decrease of the degree centralization from 1991 to 2001, the network of in-commuting shows the greater degree of centralization, in the two periods under review, suggesting a greater centralization and polarization of commuting flows in terms of inflows (indegree) than in terms of outflows (outdegree). Both in 1991 and in 2001, Lisboa is the municipality that occupies the central position in relation to inflows, and Sintra is the more central municipality in what concerns the outflows.

The degree of nodal distance is measured by the network *diameter*⁷ and is similar in both periods, indicating the absence of significant changes or the same level of efficiency in terms of distances between the commuting nodes. In 1991, the longest distance covered on the home-to-work trips was between Abrantes and Freixo de Espada à Cinta, and in 2001, it was among Alandroal and Mondim de Basto.

The degree of agglomeration or clustering of the network (measured by the *clustering coefficient*⁸) of the network of commuting, is greater in 2001 than in 1991, showing a higher concentration and/or clustering of groups of municipalities (clusters) with similar characteristics of commuting.

By using the software Pajek, graphs were built (Figures 1 and 2) that correspond to graphical representations of the commuting network in 1991 and 2001, representing urban areas defined according to the criterion of more than 3,500 daily commuters (Hall et al., 2006).⁹

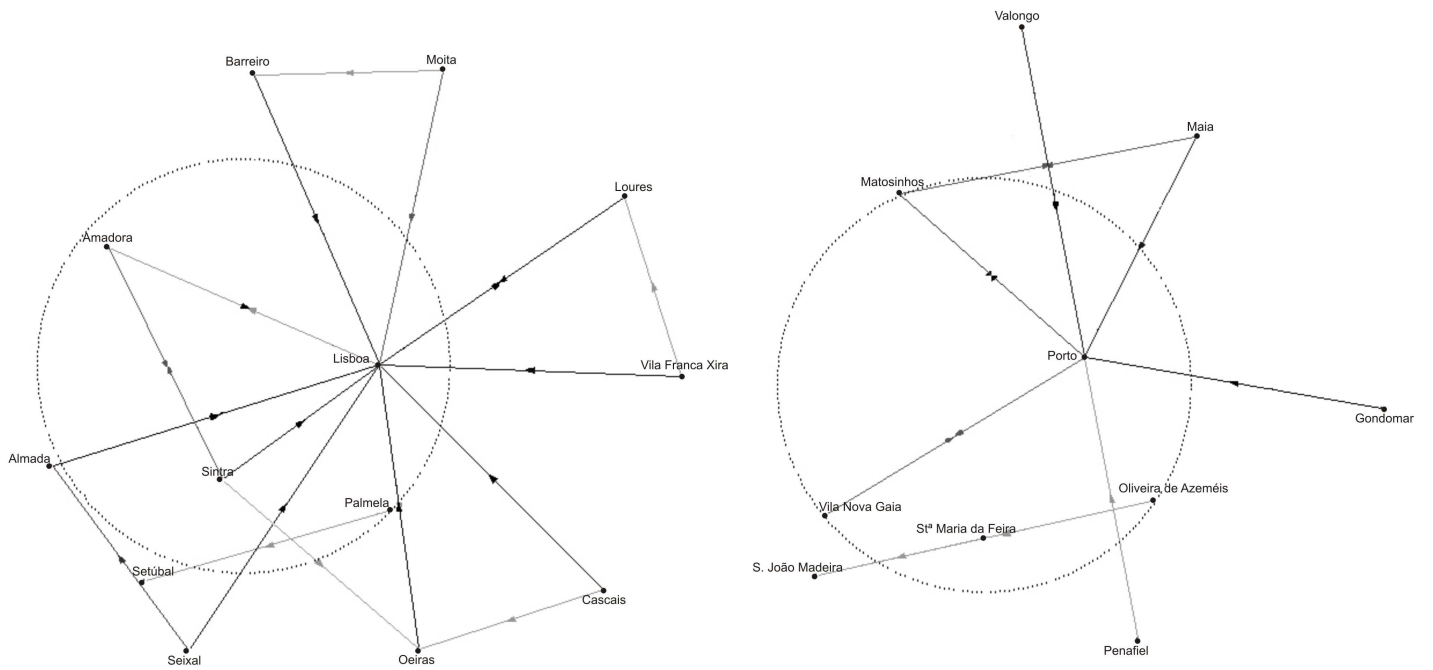
⁶ The *degree centralization* is a measure of local centrality obtained by the number of direct connections a node or adjacent states (the ones that send the most receiving) with the remaining network nodes.

⁷ The *diameter* is the largest geodesic distance of a network that measures the degree of separation between nodes.

⁸ The *clustering coefficient* gives us the degree of agglomeration or clustering of the nodes in a network, as measured by the average of local clustering coefficients of all network nodes.

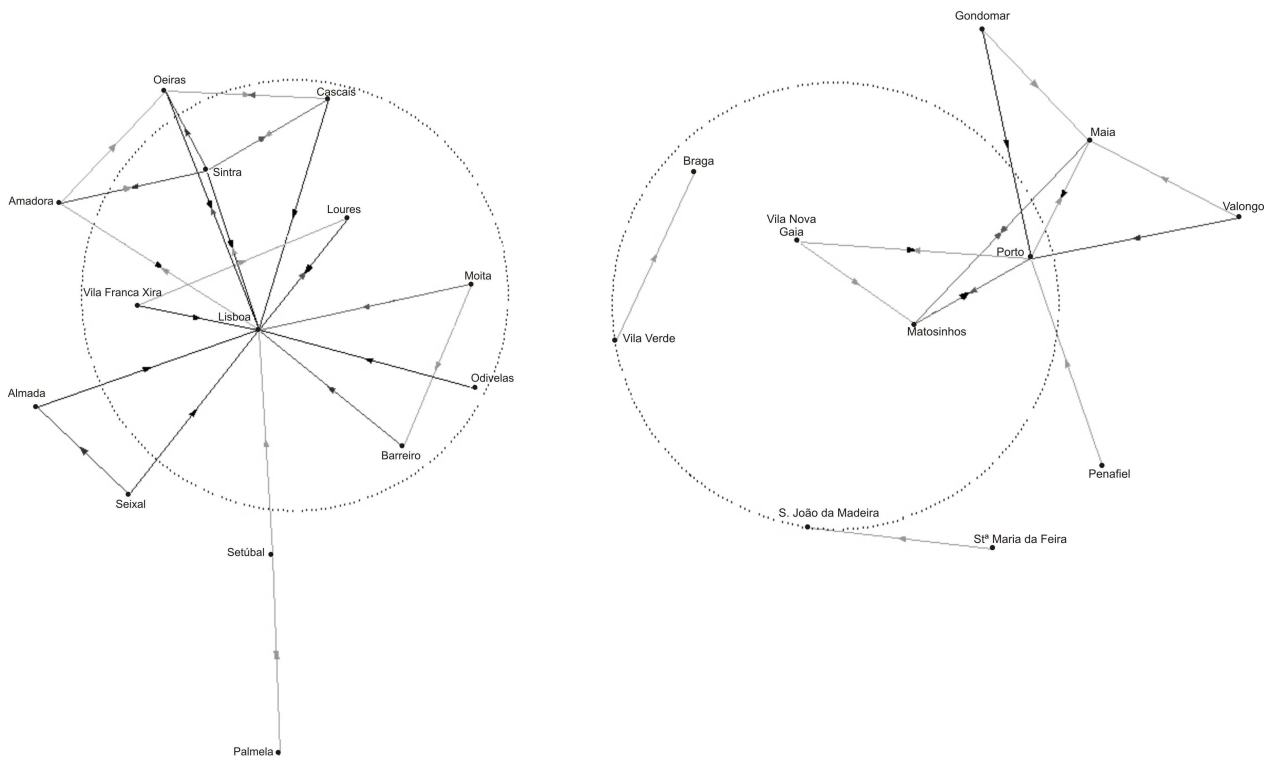
⁹ To this end, it was selected the default format of the Pajek network *Circular* and the options of representation Energy and Kamada-Kawai free, letting the program automatically decide the location of the nodes and the node to be placed in the center of the graph.

Figure 1 - Urban regions with more than 3 500 commuters: 1991



Source: Own computations, from INE (1991).

Figure 2 - Urban regions with more than 3 500 commuters: 2001



Source: Own computations, from INE (2001).

The previous graphs show, in 1991 and in 2001, two polycentric urban regions that coexist with the central cities of Lisboa and Porto and the areas they polarize, i.e., their respective metropolitan areas (INE and MOPTH, 2003)¹⁰.

4.3. Cluster analysis

The Cluster Analysis has been used in several empirical studies of the functional polycentrism (Modarres, 2003; Trullén and Boix, 2003; Baumont et al., 2004), and it has been also used in this study in order to assess the relationship of proximity and (di) similarity between the municipalities by class of commuting (in and out), by using the ascendant hierarchical clustering

Based on the criteria of Hall et al. (2006)¹¹, it was made an initial partition of the network of commuting by grouping classes into hierarchical groups of commuting flows (range of flows), demarcated according to the following scale:

Class 1: between zero and 300 commuters daily

Class 2: 300 to 3,500 daily commuters

Class 3: 3500 to 10,000 daily commuters

Class 4: 10,000 to 50,000 daily commuters

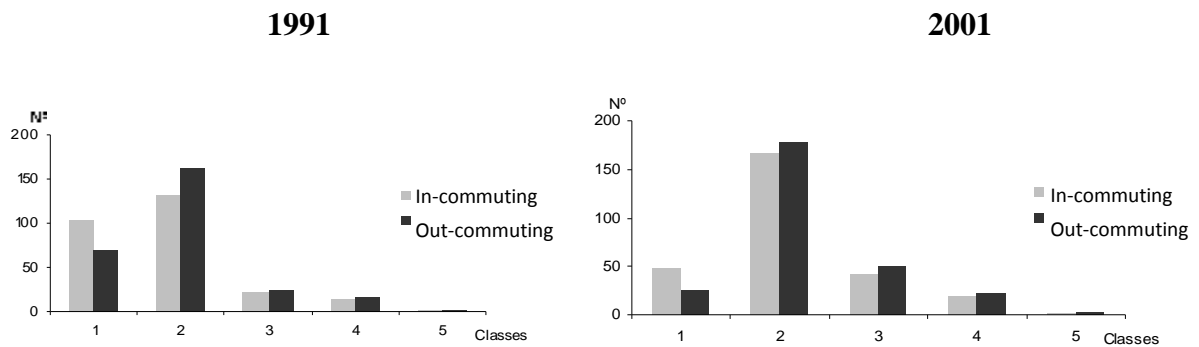
Class 5: over 50 000 daily commuters

After that, a graphical representation of the classes of frequencies of the commuting flows previously defined was made (Figure 3):

¹⁰ It should be noted that, according to the same criterion of delimitation of urban areas with more than 3.500 daily commuters in 2001, there have been 4.234 flows from Olhão to Faro and 4.631 flows from Ílhavo to Aveiro. These nodes are not represented in the preceding figures because they do not belong to the metropolitan areas examined (Lisboa and Porto).

¹¹ Hall *et al.* (2006) consider the criterion of 3.500 or more daily commuters to set monocentrism, and the criterion between 300 and 3,500 daily commuters to define polycentrism.

Figure 3 - Commuting classes



Source: Own computations, from INE (1991, 2001).

The analysis of the previous figure allows us to verify that the flows of out-commuting are higher than the flows of in-commuting, for all classes of commuting, except in class 1 (less than 300 daily commuters), both in 1991 and 2001.

There is also a higher concentration of commuting flows in classes 1 and 2, being class 2 (with daily commuters between 300 and 3.500) concentrating the largest number of municipalities: 48% of all municipalities in 1991 and 60% of all municipalities in 2001.

Additionally, it is observed a decrease of the commuting flows in class 1 from 1991 to 2001, which include small size nodes, while classes 3 and 4 record, from 1991 to 2001, an increase of the commuting flows, which confirms the intensification of commuting in larger nodes and the increase of the nodal dispersion. Finally, class 5, with more than 50.000 commuters, did not change from one period to another, as only two municipalities (and the same) lie in this class, in the following order: Amadora and Sintra, in terms of out commuting and Lisboa and Porto, in terms of in-commuting. This result suggests an urban system bipolarized around two central cities: Lisboa and Porto (Albergaria, 1999; MOPTH and INE, 2003; Delgado and Godinho, 2006).

Following this initial characterization, the research proceeds by using Cluster Analysis, more precisely, the ascending hierarchical clustering and by employing the agglomerative

method based on the *farthest neighbor* (*complete linkage* or *furthest neighbor*¹²) and the distance used was the Euclidean distance¹³ (Sharma, 1996; Maroco, 2007).

The procedure of ascending hierarchical clustering operates on the basis of (di) similarity and relative distance of nodes to be grouped. In this work, it was choose the method of farthest neighbor because it tends to produce more compact clusters (Sharma, 1996; Maroco, 2007). The results obtained in the clustering of municipalities by class of commuting allowed obtaining the following statistical indicators (Table 3):

Table 3 – Statistics of the Commuting network: 1991, 2001

Indicators		Class 1		Class 2		Class 3*		Class 4*		Class 5*	
		In	Out	In	Out	In	Out	In	Out	In	Out
1991	Mean	1 308.38	1 636.58	13 385.00	29 246.57	17 605.00	53 138.00	277 980	28 450	113 194	23 573
	Std. Deviation	2 114.28	2 665.61	5 708.96	5 407.97	3 654.56	8 785.99	0	0	0	0
2001	Mean	2 149.32	2 559.79	20 271.58	41 619.58	365 887	37 113	132 509	26 809	27 075	97 417
	Std. Deviation	3 255.62	3 250.30	9 656.19	9 128.62	0	0	0	0	0	0

* Classes with one observation.

Source: Own computations, from INE (1991, 2001).

Since in the hierachical clustering the formation of classes is done by stages, it is not possible to compare the same classes in different years because the classification is made independently in both periods.

Thus, from the above table it is observed, for 1991 and 2001, an increase of the average and standard deviation of the commuting flows (in and out) in all classes in either period, indicating, an intensification of the commuting flows in general, i.e., the density of the network of commuting increased.

Additionally, the average of in-commuting flows is lower, in all classes, than the average of out-commuting flows, i.e., the network register more commuting flows in terms of outflows (outdegree) than in terms of inflows (indegree).

In terms of classes of commuting, the average and standard deviation of commuting flows recorded higher values, in classes 3 and 4 in 1991 and in classes 3, 4 and 5 in 2001, suggesting that the two periods under review, there is an intensification of flows in larger nodes.

¹² In the complete linkage (or furthest neighbor), after the first cluster is formed, the distance to the other objects is the largest of the distances from each of the elements of this cluster to each of the remaining objects (Sharma, 1996; Maroco, 2007).

¹³ The Euclidean Distance is a measure of metric dissimilarity that measures the length of the straight line that joins two points in a p-dimensional space (Maroco, 2007).

It is also observed that class 1 is, in 1991 and 2001, the one with the lowest mean and standard deviation, despite the fact that this class comprises the largest number of nodes of commuting, showing an urban system that consists mainly, in terms of commuting, by nodes with a small scale or with few polarizing centers. In turn, the class 2 is the one that, in 1991 and 2001, registers average values of out-commuting more than the double of the average values of in-commuting, suggesting a pattern of dominance of outdegree flows over indegree flows, in either period.

Still, in 1991, class 3 records an average value of out-commuting more than triple of the value of in-commuting, showing the position of these cities as ‘senders’ of flows while the class 4 (comprising the municipality of Lisboa) emerges as a class ‘central’ in terms of in-commuting as it registers 277 980 entries, followed by class 5 (comprising the municipality of Porto) as it registers 113 194 entries. In 2001, class 3 (comprising the municipality of Lisboa) and class 4 (comprising the municipality of Porto) reveal, as in 1991, their positions of ‘leadership’ in terms of in-commuting or indegree. Finally, in 2001, class 5, made by the municipality of Sintra, assumes a position of ‘prominence’ in terms of out-commuting or outdegree as it registers a outflow of 97 417, i.e., Sintra is the municipality with the highest degree of nodal outflows (which also records in 1991).

In short, it appears that the cities of Lisboa and Porto are the nodes that experience, both in 1991 and in 2001, the maximum indegree, i.e., the highest nodal degree of inflows. The results then confirm the position of *leadership* engaged by these municipalities as polarizing nodes of employment. By contrast, in both periods, the municipality of Sintra is one who registers the maximum outdegree, i.e., the highest degree of nodal outflows, and as such, the primary node ‘sender’ of employment.

On the other hand, class 2, which was formed in 1991 by a group of municipalities of Almada, Cascais, Gondomar, Maia, Matosinhos, Seixal and Vila Nova de Gaia and the new class 2 in 2001, which also include the municipalities of Amadora, Loures, Odivelas, Oeiras, Vila Franca de Xira, show, besides the increase of nodal spread, a similar pattern of commuting from these municipalities, that is, an increasing polarization of employment in larger nodes, as previously had been reported.

5. Final remarks

This work had as main objective the evaluation of functional polycentrism in Portugal, using, for this purpose, the Social Network Analysis and the Cluster Analysis. The results undertaken suggest the increase in the commuting flows between 1991 and 2001, revealing an increase of intra-municipal movements (+7.1%) and especially of the inter-municipal movements (+48.5%). It is also observed an increase of the density (or connectivity) of the network of commuting, from 1991 to 2001. This reveals an increased number of connections or flows of commuting, despite the fact that, for some municipalities, it is observed an absence of functional interaction or the existence of insignificant values of commuting.

There is also a network of commuting more dispersed and more clustered in 2001 compared to 1991, given the greater degree of proximity (closeness centralization) and the lowest degree of intermediation (betweenness centralization) in 2001, compared to 1991. This might indicate either a decrease in the commuting flows for middle-size nodes, or an increase of such flows in larger nodes, or even the concentration of employment in nodes with less difficulty in commuting. There is even a greater centralization and polarization of the flows of commuting and employment, in terms of inflows (indegree) than in terms of outflows (outdegree). There is also a higher degree of agglomeration (clustering coefficient) in 2001 than in 1991, showing a network of commuting more clustered in 2001 than in 1991.

Generally, the results suggest that the Portuguese urban system has, from 1991 to 2001, a denser network of commuting (commuting flows increased), with less need for intermediation in travel, less centralized, more dispersed and more clustered or agglomerated.

It should be noted, finally, and as suggestions for future research, the possibility of joint consideration of indicators of morphological and functional polycentricism. Another possibility is the use, if available, of other variables to evaluate the polycentric system (e.g., business travel, business emails, travels by rail or by road, provision of advanced producer services, etc.). Finally, another suggestion is to extend this methodology to use other measures of assessment and evaluation of networks, such as the analysis of subgroup or n-clicks.

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