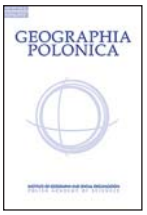

Geographia Polonica
Volume 86, Issue 3, pp. 183-198
http://dx.doi.org/10.7163/GPol.2013.18

INSTITUTE OF GEOGRAPHY AND SPATIAL ORGANIZATION
POLISH ACADEMY OF SCIENCES
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POLYCENTRIC CITY NETWORKS IN CENTRAL-EASTERN EUROPE: EXISTING CONCEPTS AND EMPIRICAL FINDINGS

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Abstract

The concept of polycentricity has gained significance in discussions on spatial development in Europe in recent years. This paper presents new evidence on polycentric city networks in Central-Eastern Europe based on selected results of the ESPON project POLYCE (Metropolisation and Polycentric Development in Central Europe). The authors discuss existing applications of the concept in the context of EU spatial policies and present an exploratory analysis of relational polycentricity focused on international networks of firms and research co-operation between seven capital cities in Central-Eastern Europe (Vienna, Bratislava, Prague, Warsaw, Berlin, Budapest and Ljubljana). Analysis of networks of firms in the advanced producer service sector reveals strong ties between Budapest, Prague, Vienna and Warsaw, with Berlin being less connected but hosting firm subsidiaries of higher order. The investigations on research networks within EU Research Framework Programmes demonstrate that Berlin and Vienna play dominant roles in research co-operation within the region and are also well integrated in European scientific communities. There is no clear indication that inter-urban firm and research networks are influenced by travel times or ethnic ties between the cities, but the similar structures of firm and research relations suggest that different kinds of interactions, networks and co-operation between cities often go hand in hand with each other and are connected in some way.

Key words

relational polycentricity • firm relations • research networks • capital cities • Central-Eastern Europe

Introduction

The concept of polycentric development has played a central role in the discussion of spatial development in Europe over the last 15 years. An overview of relevant literature shows that it is applied as an analytical and a normative concept and can refer to both morphological and relational aspects of spatial structures on different spatial levels. In this context the paper presents selected and revised results from the ESPON project POLYCE (Metropolisation and Polycentric Development in Central Europe), which investigated polycentric development in five capital cities in Central Europe (Vienna, Prague, Budapest, Ljubljana and Bratislava) as an empirical basis for developing metropolitan growth strategies. Extending the thematic scope and city sample of the ESPON analysis, this paper presents findings on the extent of relational polycentricity between seven selected capital cities in Central-Eastern Europe (Vienna, Bratislava, Prague, Warsaw, Berlin, Budapest and Ljubljana).

The paper starts with a short overview of the application of the term 'polycentricity' in the context of EU spatial policies, considering both the analytical and the normative dimension of the concept. The following two sections provide a classification of possible indicators to measure morphological as well as relational aspects of polycentricity (mainly based on recent work in the ESPON programme) and to introduce the empirical analysis of relational polycentricity by discussing existing research on relations between European cities. The empirical part of the paper then provides an exploratory analysis of networks of firms and research networks in connection with physical distances and ethnic ties. First, networks of firms in the advanced producer service sector and co-operation in European research networks are investigated by means of available data from the Global and World City Research Network (GaWC) and the EU-CORDIS database. Then, based on the hypothesis that physical distances and ethnic ties form basic conditions for other polycentric relations, the results of this analysis are put in a simple correlation analysis with travel times and ethnic ties to test for possible interdependencies. The empirical work not only covers relations between the seven selected cities, but also investigates the cities' embeddedness in European and global networks trying to reveal hierarchies and dominance in these complex urban systems. The limits and restrictions of the analysis are finally translated into conclusions, which indicate possible ways for further research in the field of relational polycentricity.

Polycentricity in European research and policies

The concept of polycentricity entered the scientific and political stage at the advent of the European Spatial Development Perspective (ESDP) in the late 1990s. In its final version the document postulates that "Polycentric Spatial Development... [should] ensure regionally balanced development... [and] help to avoid further excessive economic and demographic concentration in the core area of the EU... [in order to utilise] the economic potential of all regions of the EU" (European Communities 1999: 20). In that way the concept is very much in line with the goal of 'economic, social and territorial cohesion' as defined in the Treaty on the Functioning of the European Union. The incorporation of the 'territorial' aspect of cohesion in the Treaty in 1999 can be interpreted as an additional justification for and appreciation of spatial policies at the European level (Schindegger & Tatzberger 2002), which only have an informal status without legal or executive competences, but have indirectly influenced formal EU-policies (e.g. the common agricultural policy, environmental policy, Trans-European networks) to a certain degree. In that way the idea of polycentric development is often interpreted as a 'bridging concept' between the conflicting goals of cohesion and competitiveness causing a more balanced attention to prospering and lagging regions (Waterhout 2002). This consensual and integrative character of polycentricity has made it a central term in European Spatial Planning over the last decade. The Territorial Agenda 2020, which was enacted under Hungarian presidency in 2011, still stresses "that polycentric and balanced territorial development of the EU is a key element of achieving territorial cohesion (...), which should foster the territorial competitiveness of the EU territory also outside the core 'Pentagon area'." In that context it is also important "to avoid polarization between capitals, metropolitan areas and medium sized towns on the national scale" (European Union 2011: 7).

In the widest sense of the term, polycentricity refers to the existence of more than one spatial pole in a defined spatial entity and can both be used as an analytical tool and as a normative concept for understanding or steering spatial development processes. In that context Vandermotten et al. (2010) proposed a terminological distinction between polycentricity as an analytical concept and polycentrism as a normative policy goal, in order to avoid misunderstandings in political and scientific discussions. Many years before Davoudi (2003) was one of the first researchers who tried to unpack the concept of polycentricity by tracing its origin and its development in order to clarify the confusion about diverging interpretations and applications at different spatial scales. In a similar way Green (2007: 2097) considers that "the general concept of polycentricity has been put to a wide variety of different uses", which he attributes to the fact that "no precise, empirically testable definition of polycentricity has gained wide acceptance, even if there is a degree of consensus on what constitutes a polycentric urban region."

According to a comparative and integrative European study there are two different aspects of polycentricity: ESPON report 1.1.1 (ESPON

2005:45) makes a clear distinction between 'morphological' polycentricity "laying out the spatial distribution of urban centres in a given territory" and 'relational' polycentricity, which is "based on the networks of flows and co-operation between urban areas at different scales". Burger and Meijers (2012: 1144) confirm this differentiation of "two dominant but analytically distinct approaches" in current literature. In a similar way they conclude that morphological polycentricity "basically addresses the size of the urban centres across the territory and equates more balanced distributions with polycentricity", while functional polycentricity "takes relations between the centres into account" considering "a balanced, multidirectional set of relations between urban centres" as polycentric. According to this differentiation morphological polycentricity is about the nodal elements in a city system (e.g. hierarchy and distribution of settlements, spatial division of labour), whereas relational polycentricity depicts the edges in it (e.g. flows, interactions, networks, co-operation).

For the latter the ESPON report distinguishes two kinds of relations. There are institutional relations, which are based on 'voluntary co-operation' and rely on "co-operation and collaboration of territorial agencies to work together on joint projects and strategies" which have to be separated from structural relations, "resulting from 'spontaneous' spatial development" (ESPON 2005: 46), which cover all kinds of economic or functional relations and flows. While a distinction between morphological and relational polycentricity seems useful, the specification of relational elements appears a bit unclear and inconsistent in at least two ways. First, ESPON confines the term 'institutional relations' to territorial agencies, i.e. government bodies, and contrasts them with structural, 'spontaneous' relations. This approach ignores the fact that interactions between firms, individuals or non-governmental organisations are, in most cases, also firmly rooted in existing institutional arrangements like personal relationships, formal contracts or informal agreements. Additionally, the term 'structural' seems to be a bit confusing in linguistic terms since 'structures' refer to frameworks and arrangements rather than to something that occurs 'spontaneously'. Therefore, picking up and adopting the given ESPON terminology, it makes sense to group all kinds of relations which are 'institutionalised' in some way (e.g. collaborations of administrative bodies, networks or co-operations of firms) in one category ('institutional relations') and to distinguish them from actual flows and interactions (e.g. commuters, investments, transport of goods) which occur on the basis of these institutionalised structures and practices ('structural relations').

A second failure of this classification is the disregard of infrastructure as a main element of polycentricity. According to the underlying definitions the physical connections between the individual centres cannot be assigned to any of these categories, although they, without doubt, crucially influence the functioning of the urban system. Following the idea that morphology covers the material aspect of polycentricity, all kinds of technical infrastructure (transport, energy and telecommunication networks) would have to be allocated to the first dimension of polycentricity. On the other hand, the fact that morphological polycentricity captures the nodes of the urban system, while relational polycentricity deals with the edges between them rather suggests that infrastructure should be assigned to the second category. Irrespective of the exact classification used, which will be carried out in a rather pragmatic way in the next section, the integrative impact of any technical infrastructure makes it a key element of polycentricity which should be considered in any exhaustive classification of the term.

In this comprehensive understanding relational polycentricity is a key element of a city's territorial capital as defined by Camagni (2008). According to his theoretical taxonomy, which classifies the components of territorial capital by their rivalry on the one hand, and by their materiality on the other, relational polycentricity may be found in all kinds of components with limited rivalry. These impure public goods include 'proprietary networks', 'co-operation networks' and 'relational capital' which together represent the 'institutional' part of relational polycentricity to a large extent. Structural relations, covering all kinds of flows and interactions within or between cities, do not appear in Camagni's taxonomy, since they cannot be treated as components of territorial capital, but should rather be treated as an effect of it.

Polycentricity is also discussed on different spatial levels (Kloosterman & Musterd 2001). The ESPON report 1.1.1 distinguishes three levels of investigation:

- micro level: intra-urban or intra-regional aspects within a certain city region,

– meso level: inter-metropolitan issues within a delimited area,
– macro level: inter-metropolitan issues on a European or global scale.

The micro level emphasises "urban functional and economic complementarities" which make "co-operation and improved links" major engines of regional economic performance and "promote integrated spatial development strategies for city clusters". In a rather similar way urban complementarities are also important at the meso level since they allow the cities to specialise functionally "by offering the citizens and companies in their conjoined hinterlands access to urban functions that would usually only be offered by higher-ranking cities". At the European (macro) level polycentricity is considered to be "a useful alternative model to enhance regional development more evenly across the European territory" (ESPON 2005: 4). All these explanations clearly underline the normative dimension of the term 'polycentricity', providing applicable and practically convertible strategies for spatial planning in complex urban systems.

Measuring polycentricity on different spatial levels

Based on the definition of polycentricity the question arises how the concept can be implemented and measured in practice. Due to the multifaceted characteristics of the term it cannot be described by a single indicator but rather requires a set of indicators which cover the different aspects at all spatial levels. According to the classification specified in the ESPON 1.1.1 report, there are morphological and relational aspects to polycentricity which can be described on the intra-urban (micro) or inter-urban (meso and macro) scale. As mentioned before, however, the differentiation of relational aspects between institutional and structural relations does not include technical infrastructure between the elements of an urban system. Following the considerations given in the previous section there are good arguments for attributing infrastructure to both morphological and relational polycentricity, which makes it a rather arbitrary decision to choose one of the two categories. Since infrastructure is strongly characterized by its connecting function between different nodes in the urban system, which makes it a necessary condition for any interaction in space, we define 'infrastructural' relations as a third category of relational polycentricity in addition to institutional and structural relations (Tab. 1).

In this classification infrastructural relations cover the physical, material or built part of relational polycentricity as a basic condition for but also as a consequence of all kinds of institutional and structural relations. Based on the argumentation presented in the previous section infrastructure networks can be expected to be pre-

Table 1. Potential indicators for polycentricity.

Aspects of polycentricity	Dimensions of polycentricity	Indicators (micro level)	Indicators (meso / macro level)
Morphological	city system	rank-size distribution of municipalities (population / employment)	rank-size distribution of metropolitan areas (population / employment)
	economic specialisation	spatial concentration of economic activities within metropolitan areas	economic diversity of the metropolitan areas
Relational--Infrastructural	infrastructure networks	character of transport infrastructure system within metropolitan areas (travel times, capacities, comfort, etc.)	character of transport infrastructure system between metropolitan areas (travel times, capacities, comfort,etc.)
Relational--Institutional	strategic networks	inter-communal strategic and planning collaboration between municipalities	strategic alliances and political relations between cities or regions
	firm, research and social networks	networks of firms, co-operation between firms, clusters, research co-operation	locations of subsidiaries, international networks of firms, joint research projects, spatial distribution of social networks
Relational--Structural	flows and interactions	commuters, transport of goods	foreign direct investments, migration, transport (passengers, freight)

dominantly supplied by the public sector, while structural relations, including all kinds of flows and interactions, are supposed to follow individual decisions of private actors. Institutional relations can both be established by public bodies ('strategic networks') and by private organisations or individuals (here referred to as 'firm, research and social networks'). Referring to the morphological aspect of polycentricity the definitions suggest a simple differentiation: the hierarchy and distribution of settlements in a given spatial area ('city system') and the functional division of labour ('economic specialisation') can be clearly distinguished as two different dimensions of morphological polycentricity.

All dimensions of polycentricity need specific indicators for a proper description on different spatial levels. Table 1, which gives some proposals for possible indicators, should not be considered as a comprehensive or complete list, but just shows some pragmatic ideas, how these different aspects and dimensions of polycentricity could potentially be measured. Regarding the morphological aspect of polycentricity the city system can be covered by a simple rank-size distribution based on Zipf's Law (Brakman et al. 1999) of single municipalities (on the micro level) or of entire metropolitan areas (on the meso or macro level). On an intra-urban scale economic specialisation can be indicated by measures of spatial concentration of economic activities within a metropolitan area, while the inter-urban approach needs a comparative analysis of economic structures (especially the existence of dominant branches) in different metropolitan areas in order to reveal economic diversities and complementarities between them.

As for relational polycentricity, infrastructure networks (e.g. transport, energy, water, telecommunication) may refer to the shape and the quality of the system within (micro level) or between (meso or macro level) metropolitan areas. This may include capacities and costs, but also travel times, accessibility and travel comfort of a given transport infrastructure. Structural relations, which cover actual flows and interactions between the nodes of an urban system, can be analysed through different kinds of data. On the micro level most statistics offer commuter flows between single municipalities which can be considered to be largely representative for any kind of socio-economic interaction. On the meso and macro level many different kinds of interactions of people, goods, information or capital can be applied to describe inter-urban relations (e.g. foreign direct investments, migration, passengers or freight). The assessment of institutional relations has to cover government-related strategic networks, which requires a qualitative analysis of inter-communal strategic and planning collaboration between different municipalities on the micro level, or of strategic alliances and political relations between cities or metropolitan regions on the inter-urban scale. Finally, the assessment and acquisition of relevant data on relations between 'private' actors, which include a broad variety of relations between firms, entrepreneurs, research institutes, non-governmental organisations, associations or individuals, definitely needs innovative ideas and creative efforts in the empirical work. Therefore, the following sections will discuss potential approaches, indicators and data sources which could be exploited for the assessment of inter-urban interaction, co-operation, and networks.

Relational polycentricity in CEE capital cities: An empirical approach

In trying to apply the concept of relational polycentricity on a meso/macro level, this paper builds on existing research on the geography of inter-urban relations. There are various approaches to evaluating functional linkages between cities and regions, which are based on different kinds of data (e.g. commuter trips, telephone calls, intra-firm and inter-firm networks) and provide diverging results: "The spatial organisation of each of these types of functional linkage is not necessarily similar and, therefore, a region may appear polycentric and spatially integrated with respect to one type of functional linkage but monocentric and loosely connected with respect to another type of functional linkage" (Burger et al. 2013). Thus, the interpretation and comparison of results from different studies has to consider the fact that the degree of relational polycentricity strongly depends on the indicators used and always refers to the specific conditions in a particular spatial area. The lack of consistency in the definition and implementation of the term incited Green (2007) to develop a formal method of defining polycentricity in terms of functional connections between settlements.

Based on social network analysis he defines comparable indicators for 'Special Functional Polycentricity' and 'General Functional Polycentricity', which can easily be used to analyse real-world situations. His argument that a collection of nodes (e.g. cities, small businesses, people) can only form a system if they are balanced and functionally connected considers both the density and the balance of a network.

An interesting approach in this field of research is the interlocking network model developed by the Globalisation and World Cities (GaWC) Research Network (Taylor & Walker 2001; Taylor 2004), which was applied in different research projects and scientific papers. For instance the PolyNet project, which was funded from the European Community's Seventh Framework Programme in order to establish a platform for research co-operation and to foster transfer from science to industry within the EU, used the GaWC methodology for assessing different scales of relations between 8 metropolitan regions in Western Europe (Hall & Pain 2006). Hoyler (2011) applied the approach to the external relations of German cities from a global perspective. On the empirical foundation of a network model and data on the organisational structure of major firms specialising in advanced business services, he tried to assess and compare the integration of selected cities in the world city network. The main results reveal a rather polycentric geography of advanced producer services which, however, diverges from the spatial distribution of other metropolitan functions. Contrary to this top-down approach Lüthi et al. (2012) adapt the network model from a bottom-up perspective. They suggest different approaches to revealing the relational geography of the knowledge-based economy by determining the networking activities of advanced producer services and high-tech firms in Germany. In addition, they implement a value chain analysis based on a survey of 391 knowledge-intensive enterprises, complemented by in-depth interviews with managing directors. The results provide interesting insights into the functional urban hierarchy in Germany and question the traditional view of nested hierarchies as an organising principle of space.

In Poland, the discussion of polycentric development has intensified over the last couple of years and reached a first climax during EU-presidency in 2011. A special issue of the main periodical of the Committee for Spatial Economy and Regional Planning of the Polish Academy of Sciences (Komornicki & Siłka 2011) was especially devoted to functional linkages between Polish metropolises. Smętkowski (2011) analyses networks of global companies, transport relationships and scientific linkages focusing on the role of Polish cities in Europe. Considering Metropolitan European Growth Areas (MEGAs) in their regional surroundings he tries to bridge the gap between the different spatial levels of polycentricity without, however, explicitly establishing the link between intra-metropolitan morphology and the integration in inter-urban networks. Śleszyński (2011a: 60) investigates economic linkages using the empirical base of the locations of firms and the inter-agglomeration organisational and ownership linkages of the biggest enterprises in Poland, basically concluding that "the higher levels of administrative and settlement hierarchy exhibit a high concentration of economic linkages". In a second contribution Śleszyński (2011b) also tries to capture social linkages by data on migration flows and marriages. In a very detailed analysis of relational data he demonstrates an increasing process of demographic polarisation in Poland. Komornicki (2011) examines transport connections between Polish metropolises specifying travel times, travel speed and number of connections in different modes of transport and concludes by defining the 'multimodal daily accessibility' of Polish metropolises.

In a similar way, the empirical part of this paper tries to define indicators for inter-urban relations and to use them with suitable data for seven capital cities in Central-Eastern Europe (CEECC)[1]. This selection of cities is based on the ESPON project POLYCE, which investigated polycentricity and metropolisation within and between the city regions of Vienna, Prague, Budapest, Ljubljana and Bratislava. Since the main objective of the project was the strengthening of city networking in CEE, the city sample reflects the strong political will of five city administrations to deepen their relations. In this paper, however, the cities of Berlin and Warsaw are included in order to enlarge the geographical scope of the analysis. In that way the empirical results refer to selected aspects of relational polycentricity in seven CEE capital cities, including 5 European Metropolitan Growth

[1] In the whole paper the abbreviation 'CEE' indicates Central-Eastern Europe, while 'CEECC' stands for the seven selected capital cities in Central-Eastern Europe.

Areas (Berlin, Warsaw, Vienna, Prague, Budapest) and 2 medium-sized cities (Ljubljana, Bratislava), which differ greatly in population size, economic structure and metropolitan functions. The analysis does not aim at a comprehensive investigation of relational polycentricity, but (according to the limited availability of relevant data) concentrates on the following aspects:

- networks of firms (location of subsidiaries of international companies from the APS-sector);
- research networks (project co-operation in the EU-Framework Programmes);
- travel time (actual travel time between two cities by road and rail);
- ethnic relations (share of foreigners in the home country of the related city).

Referring to the taxonomy given in the previous section the first two issues, which are the main objects of the empirical research, can clearly be attributed to the category of institutional networks between 'private' actors. They are both closely connected to the third (specifying the infrastructural aspect of polycentricity) and the fourth topic (giving the share of foreigners as a consequence of 'structural' migration flows), which both can be interpreted as basic conditions for the development of networks of firms and research networks.

Since the data used is not able to cover the whole spectrum of the aspects investigated, the indicators given in the following sections should be treated as a first approximation. In addition to that it has to be mentioned that the data available refer to different years between 2001 and 2012, which means that they do not always reflect the very recent situation, but describe the general structure of relations between cities within the last decade.

Economic networks: Advanced producer service locations

As repeatedly argued, the situation of cities under changing conditions of accelerated globalisation can be analysed by the intensity and reach of their external linkages and by identifying their position in a global network of cities (Taylor 2004). Building on the conceptual work on the global city (Friedmann 1986; Sassen 1991) one strand of research in that field was devoted to inter-city linkages based on locations of international companies of the advanced producer service sector (APS). Following this approach the Global and World City Research Network (GaWC) provides extensive datasets which are freely accessible on the internet and have already been applied in different scientific projects and papers in this field of research (see explanations in the previous section).

The GaWC data include two relevant types of information. The mere presence or absence of a company in a city is complemented by information on the importance of a firm's location in a city (international headquarters, regional office, local office, etc.). These facts may be transferred into relational data based on the assumption that the location of firms in two cities establishes a link between these cities. From that point of view, the interaction and communication between subsidiaries of international companies can be interpreted as the edges of a network of firms covering different cities. Analyses applying this methodology have been developed, above all, by the Global and World City Research Network (GaWC) (e.g., Taylor & Walker 2001).

The dataset, which was extracted from the GaWC website and covers a sample of 100 advanced producer service firms[2] and their locations in 315 global cities for the year 2000, was used to examine the economic relationships of the seven selected CEE capital cities (CEECC). There are two types of information in the data which are exploited in the analysis: on the one hand the presence or absence of a firm in a city is used to calculate the degree of connectivity between cities, on the other hand the importance of a firm's location in a city (international headquarters, regional office, local office, etc.) provides insight into relational hierarchies between cities.

As far as connectivity is concerned, the analysis should disclose the intensity of economic relations not only among the seven cities but also between them and other cities in Europe and overseas (non-European)[3] revealing the importance of the CEE capital network in comparison to European and global networks (Tab. 2). The columns entitled 'CEECC' provide information on intra-regional

[2] Advanced producer service firms from the following branches are included: accountancy, advertising, banking/finance, insurance, law, and management consultancy. More detailed information about the dataset, as well as the dataset itself, can be found at http://www.lboro.ac.uk/gawc/datasets/da11.html.

[3] The category 'European cities' includes all of the 315 cities that are included in the database. Likewise, the category 'overseas' includes all non-European cities in the 315 cities.

connectivities (between the seven CEECC), showing the number of firms that are present in both cities. The columns 'Totals' describe the extra-regional embeddedness (with other cities) in absolute terms giving the sums of pair relations in which a city is involved. The maximum value of 3,560 overseas connection for Prague, for instance, means that the subsidiaries of the 100 registered international APS companies located in the city have a total of 3,560 potential partners in cities overseas within the framework of the company.

Concerning intra-regional connectivity, the data clearly show that there are strong ties between Budapest, Prague, Vienna and Warsaw, with a lot of relations especially between Prague and Budapest and between Prague and Warsaw. Compared to these cities, Ljubljana and Bratislava clearly fall behind, which may largely be attributed to their small size. Bratislava, however, is more connected with the other CEECC than Ljubljana. This may be attributed to the central geographical location of Bratislava compared to Ljubljana's remote location within the CEE region.

Referring to their extra-regional embeddedness beyond the CEE region, the number of relations with cities in Europe and overseas indicates that Prague, Vienna, Warsaw and Budapest are better integrated in European and global APS firm networks than the other three cities. While in Ljubljana and Bratislava this may again be attributed to the cities' small size, the low level of connectivity of Berlin is striking. Also, as regards links to overseas, the German capital falls behind the other large cities in the sample. The analysis of the relative importance of relations with the other CEECC and other European cities reveals that in both cases the relations are about equally important for the seven cities. About 3.5% of all relations occur between the CEECC, about one third with European cities. Due to the relatively low number of relations overseas, CEECC and European networks seem to be more important for Berlin than for the other cities (Tab. 2). Figure 1 illustrates these results geographically.

Since the GaWC data classify firm locations according to their importance, it is also possible to identify hierarchies in these relations and thus to make qualitative statements about relations. The basic assumption of this second analytical step is that cities with higher-ranked locations with regard to firms have a higher position in the network than cities with lower-ranked locations (headquarters vs. subsidiary). In that manner the relative importance of the CEECC within the region can be calculated very simply: for each firm that is situated in two CEECC, the city which hosts the higher-ranked location gets one point. If both locations have the same importance, each of the two cities involved gets half a point.

The matrix in Table 3 provides the results of this approach. The 'CEECC' columns show, for each pair of cities, the hierarchies in the relations between the city referred to in the row and the city named in the column. Regarding the connections between Bratislava and Berlin for instance, 12.5 firm relations are dominated by Berlin and 5.5 by Bratislava. The right part of the table provides information on the total importance of a city within the region. The column 'dominant relations' is a sum of all relations in which a city hosts a higher-ranked function (matrix summed up by row). The column 'inferior relations' is a sum of all cases in which a city hosts a lower-ranked function

Table 2. Connectivities of CEE capital cities (CEECC) based on APS firm locations, 2000.

	CEECC							Totals			Shares	
	Berlin	Bratis-lava	Buda-pest	Lju-bljana	Prague	Vienna	War-saw	CEECC	Europe	over-seas	CEECC [%]	Europe [%]
Berlin		18	34	6	37	32	35	162	1,499	2,587	3.8	35.6
Bratislava	18		26	10	27	22	21	106	1,006	1,875	3.6	33.9
Budapest	34	26		16	50	41	44	177	1,745	3,254	3.4	34.0
Ljubljana	6	10	16		15	16	14	71	662	1,395	3.4	31.3
Prague	37	27	50	15		43	46	181	1,917	3,560	3.2	34.2
Vienna	32	22	41	16	43		42	164	1,792	3,395	3.1	33.8
Warsaw	35	21	44	14	46	42		167	1,767	3,337	3.2	33.5

Source: based on GaWC.

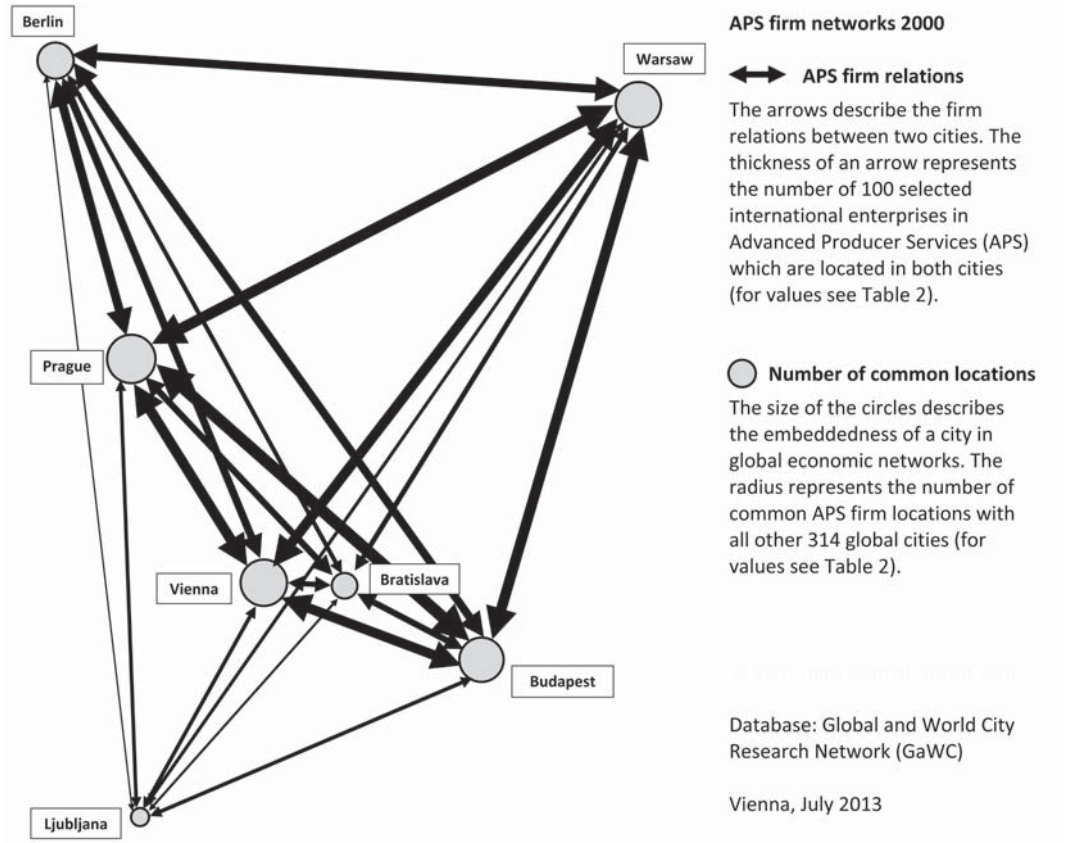

Figure 1. Firm relations in Advanced Producer Services (APS), 2000.

(matrix summed up by column). The column 'difference', which shows the difference between dominant and inferior relations, provides an insight into the total importance of a city.

The first finding of this analysis is that higher-ranked functions tend to be located in Berlin and Vienna. Warsaw, overall, is also a location for higher-ranked subsidiaries. These three cities have a positive balance of dominant and inferior relations. Berlin's dominant role seems to be especially interesting here, given its lower connectivity compared with the other four larger cities in the region. It appears that Berlin has less links than Budapest, Prague, Vienna and Warsaw but hosts more higher-ranked subsidiaries than these cities. In contrast to that, Prague and Budapest share a lot of companies with other cities, but generally host lower-ranked subsidiaries. The two smaller capitals (Bratislava and Ljubljana) are predominantly dominated by other cities in APS firm networks.

To sum up, the analysis of APS firm locations shows that there are strong connections in the CEE region between Budapest, Prague, Vienna and Warsaw. The relations between Prague and Budapest, and between Prague and Warsaw are especially strong. The larger cities are also more integrated in global networks, apart from Berlin, which falls behind in extra-regional embeddedness, and seems to be more dependent on intra-regional relations. The analysis of hierarchies within the APS relationships, however, also showed that Berlin, like Vienna and Warsaw, tends to host higher-ranked subsidiaries in the region. In contrast, Prague and Budapest, despite a high degree of connectivity in the region, tend to host lower-ranked subsidiaries.

It remains to be noted that the analysis is based on data from the year 2000. Since then, especially in the context of the current financial crisis, APS networks have most likely been subject to change.

Table 3. Hierarchies in relations of CEE capital cities (CEECC) based on APS firm location rank, 2000.

	CEECC							Location rank		
	Berlin	Bratis-lava	Buda-pest	Ljubljana	Prague	Vienna	Warsaw	dominant relations	inferior relations	difference
Berlin		12.5	18.5	5.0	21.0	16.5	18.5	92.0	70.0	+22
Bratislava	5.5		11.5	5.5	11.5	8.0	8.0	50.0	74.0	-24
Budapest	15.5	14.5		9.5	26.5	19.5	21.0	106.5	104.5	+2
Ljubljana	1.0	4.5	6.5		5.5	4.5	6.0	28.0	49.0	-21
Prague	16	15.5	23.5	9.5		20.0	21.0	105.5	112.5	-7
Vienna	15.5	14.0	21.5	11.5	23.0		21.5	107.0	89.0	+18
Warsaw	16.5	13.0	23.0	8.0	25.0	20.5		106.0	96.0	+10
Total CEECC	70.0	61.5	86.0	44.0	91.5	72.5	77.5			

Source: based on GaWC.

However, it can be assumed that in many ways these changes also followed patterns of path-dependency. In that sense, the insights provided from this empirical analysis can still be of interest for understanding economic relations in the CEE region.

Research networks: Project co-operation

Another way of measuring relations between cities is to look at co-operation between research institutions in scientific projects. The CORDIS (Community Research and Development Information Service) online database provides a useful information source for such an analysis. It includes data on participating institutions in EFP (EU Research Framework Programme) projects. Since the institutions have a clear geographical reference, the database can be exploited to identify a city's general embeddedness in European research networks and to reveal individual interrelations between the seven cities in the CEE zone. For the present analysis data for the period between the years 2001 and 2010 were extracted from the CORDIS online database and the involvement of the seven cities was analysed.

The total number of participations in EFP (EU Research Framework Programme) projects indicates that Vienna and Berlin, in particular, are excellently integrated in European research networks. Compared to Budapest, Prague and Warsaw, they participate in significantly more EFP research projects. A possible explanation for this clear difference may be found in the historical influence of networks that had grown up in the Western EU member states and which had been established over many centuries. Surprisingly, Ljubljana, in terms of research project participations, is not far behind Prague but stays far ahead of Bratislava, although Ljubljana is smaller in population and employment.

In order to get some idea about hierarchies and functional dependencies in these research networks, the location of the lead partners can additionally be investigated. Unfortunately, the CORDIS database only gives the nationality of the lead partner without giving its name or its home city. This limitation becomes a problem if a country hosts more than one participant, because in this case it is not evident which of these partners is leading the project. Consequently, the share of projects, which have a 'domestic' lead partner, also includes projects led by an institution located somewhere else in the country. Since the seven CEECC play a dominating role within their countries (with the exception of Berlin and Warsaw), this inaccuracy may well influence the results but does not completely distort them. The values given in Table 4 clearly demonstrate the dominant role of Berlin and Vienna in EU-research projects. A share of almost 30% of projects led by German and Austrian institutions suggests that the two cities play a central role in many scientific networks. In this respect Warsaw and Budapest, with shares of 16% and 13% respectively, perform a bit better than the remaining three cities where just below 10% of the projects are led by a domestic institution. These results clearly indicate that Vienna and Berlin play the most central role in EFP research

projects in this city sample and also lead a comparatively much higher share of projects than the other cities.

Table 4. Participation in European Framework Programme projects, 2001-2010.

	Project participations	Domestic lead partner[1]	
	2001-2010	total	share [%]
Berlin	1,689	572	33.9
Bratislava	502	48	9.6
Budapest	1,539	202	13.1
Ljubljana	919	75	8.2
Prague	1,271	119	9.4
Vienna	2,088	613	29.4
Warsaw	1,341	219	16.3

[1] Number of projects with participation of research institutes located in the city and led by an institution located in the same country.
Source: CORDIS database.

The second, more relevant part of the examination of the CORDIS data focuses on the links between the seven cities in EFP research projects. For that purpose, the number of projects in which two of the seven CEECC take part was collected. Since the query was carried out separately for all pairs of cities double counts could not be avoided. Therefore, the numbers and shares given in Table 5 must not be added for different relationships.

The highest number of research co-operations in the period between 2001 and 2010 can be detected between Vienna and Budapest, but Vienna is also closely connected to Berlin and Warsaw. Interestingly, Ljubljana, despite its distant location in the region, is doing significantly better than Bratislava. The shares in the numbers of co-operation links of all project participations, which reflect the importance of intra-regional research co-operation for the seven cities compared to 'external' networks with other partners, reveal that Bratislava and Ljubljana are both rather dependent on the region while Vienna and Berlin seem to be better integrated in other European networks.

Figure 2 illustrates the results mentioned above: Vienna and Berlin have, in total, the most project participations, with strong links to some of the other CEECC. Bratislava appears to be fairly isolated in the region, while Ljubljana is doing comparatively well.

Relevance of travel times and ethnic relations

Contrary to theories postulating the decreasing importance of physical distance in the post-industrial information society (e.g., Cairncross 1998), there is empirical evidence that the location of economic actors still strongly determines their behaviour and decisions. Kramar (2010) claims that physical distance, which determines transport costs and spatial accessibility, still significantly influences knowledge-intensive activities in spite of advancing technologies in telecommunication. From that point of view, travel times, reflecting geographical distances, can be considered an important determining factor of actual flows, interactions and relations between different cities. For this reason the average travel times between the seven cities were collected for road and rail connections by querying online travel time databases (ViaMichelin, Austrian Federal Railways).

Table 5. Participation in European Framework Programme projects in CEECC, 2001-2010.

	Berlin		Bratislava		Budapest		Ljubljana		Prague		Vienna		Warsaw		Total
	no.	share [%]	no.	share [%]	no.	share [%]	no.	share [%]	no.	share [%]	no.	share [%]	no.	share [%]	no.
Berlin			68	4.0	217	12.8	120	7.1	190	11.2	297	17.6	188	11.1	1,689
Bratislava	68	13.5			148	29.5	101	20.1	123	24.5	158	31.5	120	23.9	502
Budapest	217	14.1	148	9.6			198	12.9	253	16.4	351	22.8	288	18.7	1,539
Ljubljana	120	13.1	101	11.0	198	21.5			149	16.2	232	25.2	187	20.3	919
Prague	190	14.9	123	9.7	253	19.9	149	11.7			244	19.2	222	17.5	1,271
Vienna	297	14.2	158	7.6	351	16.8	232	11.1	244	11.7			295	14.1	2,088
Warsaw	188	14.0	120	8.9	288	21.5	187	13.9	222	16.6	295	22.0			1,341

Source: CORDIS database.

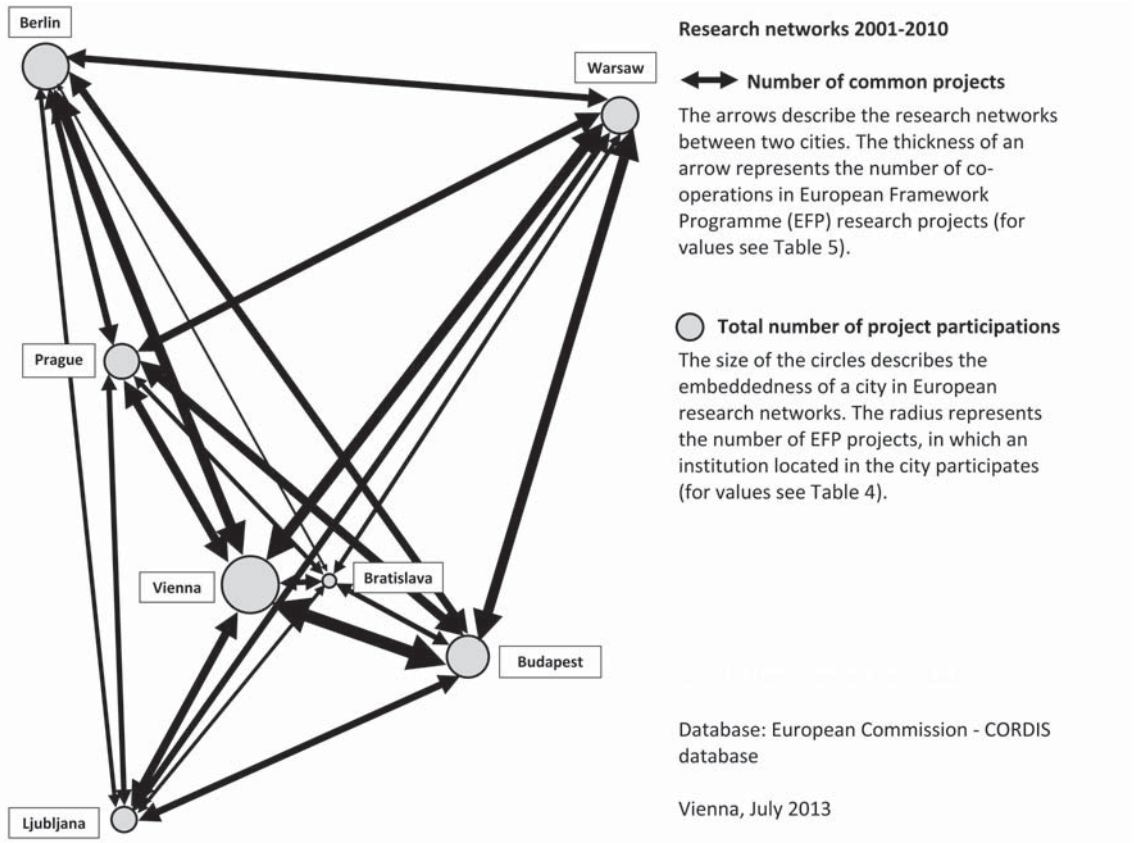

Figure 2. Research co-operations in European Framework Programmes, 2001-2010.

The ratio between travel times to all other cities by car and by train gives an insight into the relative appeal of rail services: the lower the ratio, the more attractive the supply of rail services in a given city (Tab. 6). Flight times were not considered since the small distances between some of the cities (especially between Prague, Vienna, Bratislava and Budapest) make aviation almost irrelevant for many relations within the region.

The analysis reveals that Bratislava and Vienna are the most accessible of the seven cities. Travel times from these two cities to all the other cities are the shortest in total, which is certainly related to their central geographical location in the city

Table 6. Travel times (road and rail) in minutes, 2012.

	Berlin		Bratislava		Budapest		Ljubljana		Prague		Vienna		Warsaw		Total		
	road	rail	road	rail	road	rail	road	rail	road	rail	road	rail	road	rail	road	rail	ratio
Berlin			405	543	510	707	553	763	225	280	423	556	424	324	2,540	3,173	1.25
Bratislava	402	545			117	161	259	426	191	228	54	57	461	455	1,484	1,872	1.26
Budapest	508	709	118	152			272	507	297	405	143	155	567	619	1,905	2,547	1.34
Ljubljana	558	815	260	453	274	513			421	651	231	347	693	857	2,437	3,636	1.49
Prague	225	278	193	252	297	416	420	659			211	265	507	502	1,853	2,372	1.28
Vienna	422	564	54	58	143	156	229	336	211	269			483	491	1,542	1,874	1.22
Warsaw	425	332	464	448	570	612	696	883	509	507	487	479			3,151	3,261	1.03

Source: ViaMichelin, Austrian Federal Railways.

network. Warsaw and Berlin, on the contrary have the worst accessibility with regard to the other cities. Compared to travel times by car, however, Warsaw shows the highest relative rail accessibility, which is clearly lowest in Ljubljana.

Economic and social interaction is firmly embedded in existing institutionalised networks, relations and traditions. From that point of view, the hypothesis that ethnic and historical ties between places (e.g. common history, culture, language) play a crucial role for the constitution of interactions seems to be worth investigating. A first approach to implementing this aspect of the study using the data available is to consider ethnic relations based on nationalities. That was done by collecting the number of inhabitants with the other country's nationality and comparing it to the total number of foreigners (from the seven CEE countries, EU27-countries and all other countries). Due to the lack of complete data at city level, the indicator could only be provided for the home countries of the seven cities in the year 2008. In spite of these limitations the data give an interesting insight into the ethnic and historical ties between the CEE countries which have developed over many decades or even centuries and which can be assumed to influence current relationships between their capitals.

The results show that Austria and Germany are the most 'international' states with the highest share of foreigners in total, which reflects their important role as immigration countries over the last century (Tab. 7). The ethnic ties between the two countries are reflected by the number of people living in one country holding the other country's citizenship. The data, not surprisingly, mirror historic relations between countries. There are many Polish people living in Germany, Slovakians living in the Czech Republic and Austrians living in Germany. In the cases of Germany and Poland, as well as Slovakia and the Czech Republic, the relations are fairly asymmetrical, with the former, in both cases, hosting a greater number of foreigners from the latter than vice versa. This asymmetry is less pronounced in the relations between Germany and Austria, which had rather balanced migration in both directions over recent decades.

As argued before, it can well be assumed that there are mutual interrelations and dependencies between travel times and ethnic ties on the one hand and the quantity of firm and research relations on the other. Although all the indicators given can only be considered and interpreted as proxies for relational polycentricity and they only cover a sample of 21 relations between seven cities, they seem to be reliable enough to test this hypothesis in a simple correlation analysis.

In contradiction to the argumentation given above, the results shown in Table 8 give no statistical evidence on a correlation between travel times and inter-urban firm and research networks. In almost the same manner the correlation coefficients between the number of foreigners from the other country (in both directions) and the actual relations can hardly be used to prove an interrelation in a reliable way. The most significant result is the clearly positive correlation between the extent of firm and research relations, which supports the hypothesis that different kinds of interactions, networks and co-operation between cities often go

Table 7. Foreigners: population by citizenship (national level), 2008.

	Foreigners from								Share of foreigners [%]		
	Germany	Slovakia	Hungary	Slovenia	Czech Republic	Austria	Poland	CEE countries	CEE countries	EU27	total
Germany		25,987	60,221	22,336	36,418	191,931	413,044	749,937	0.91	3.06	8.82
Slovakia	2,889		2,702	132	5,965	1,472	4,015	17,175	0.32	0.48	0.76
Hungary	14,436	4,944		133	284	2571	2645	25013	0.25	1.00	1.76
Slovenia	625	457	127		118	295	169	1791	0.09	0.20	3.39
Czech Rep.	15,700	67,889	587	211		3373	20,601	10,8361	1.04	1.27	3.35
Austria	119,807	15,665	19,318	6,973	8287		35,485	205,535	2.47	3.48	10.04
Poland	11,844	256	457	13	634	2730		15,934	0.04	0.07	0.15
CEE countries	165,301	115,198	83,412	29,798	51,706	202,372	475,959	1,123,746	0.72	1.98	5.61

Source: EUROSTAT.

Table 8. Participation in European Framework Programme projects.

	Travel times[1]		Ethnic ties[2]	Relations[3]	
	car	train	foreigners	firms	research
Firm relations (GaWC)	+0.028	-0.088	+0.151	+0.698	
Research relations (CORDIS)	-0.051	-0.296	+0.177		+0.698

[1] Average travel time between the two cities in both directions.
[2] Population with the other country's nationality (in both directions).
[3] Absolute number of relations between the two cities.

hand in hand with each other and are connected in some way.

In this context it would be very helpful to make other data sources available and to broaden the sample of cities, in order to get more significant and stable results on dependencies, discrepancies and determining factors of inter-urban relations.

Conclusions

An overview of recent relevant literature reveals the heterogenous character of the concept of polycentricity, which is used in diverging definitions, interpretations and applications at different spatial scales. The relational dimension of polycentricity, which deals with all kinds of relations between urban centres, seems to be especially significant on the current agenda for spatial research in Europe with a lot of projects and publications trying to define and implement the concept both in its analytical and in its normative dimension. Since European discussion focuses strongly on the macro level of relational polycentricity, the investigation of flows, co-operation and networks between different cities and metropolitan regions in Europe offers a lot of potential for future research through the consistent consolidation and adjustment of a diverging terminology, the transparent definition and implementation of applicable indicators and the creative detection and exploitation of new databases which are the main challenges for a comprehensive and sensible assessment of inter-urban networks.

In that context the paper explores potential indicators to measure relational polycentricity and to illustrate their applicability for seven capital cities in Central-Eastern Europe. The indicators used for describing networks of firms and research networks permit the following conclusions to be drawn. Firstly, in terms of networks of firms in Advanced Producer Services (APS), the GaWC data indicate that there are strong ties between Budapest, Prague, Vienna and Warsaw. Berlin is quantitatively less connected, but hosts more subsidiaries of firms with a higher range of influence, which makes the German capital a central player in the region. Secondly, in terms of research networks, data on project participations in European Framework Programmes reveal that Vienna and Berlin play a dominant role in the CEE region, in which the strongest ties exist between Vienna and Budapest, Berlin and Vienna and between Warsaw and Vienna. There are some similarities but also clear differences between firm and research networks in the region. Not surprisingly, the big cities perform well in both cases. More specifically, Berlin, and to a lesser extent Vienna, play central roles in both fields. Concerning differences, Prague plays a strong role in firm networks but much less so in research networks. The different role of the two medium-sized cities in the region is also striking. While Bratislava is more integrated into APS-firm networks, Ljubljana has a relatively strong role in research cooperation.

The limited results of the empirical analysis suggest possible routes for further research. Although the analysis reveals the structure of the inter-urban networks of the seven cities selected by describing the intensity of relations between pairs of cities, it cannot provide results on the network closure compared to other regions in Europe. Therefore a comparative analysis of relational polycentricity in similar transnational urban systems in Europe could be helpful. Furthermore, the investigations should cover a broad variety of relations between firms, entrepreneurs, research institutes, non-governmental organisations, associations or individuals, which means that additional data sources have to be detected and exploited in order give a more comprehensive picture of relational polycentricity. The investigation of different kinds of firm networks (e.g., in

industry, trade or commerce), the examination of social networks (e.g., through the Web) or the consideration of different kinds of human interaction (e.g., tourism, migration) could provide additional information on flows, co-operation and networks between cities. Of course all indicators should be implemented with the most recent data available in order to give an exact description of the current situation. In that context, the acquisition of the data at regular intervals could yield additional insights. Such a dynamic approach could identify changes over time or even reveal the influence of external trends on relational polycentricity. From a methodological point of view, innovative network indicators (based on classical graph theory) and more complex methods of analysis (e.g. interaction models) could help to refine the results on the structure, functionality or main determining factors of inter-city networks. The political relevance and usability of the investigations could also be enhanced by a more detailed examination of causal interdependencies between the indicators. The discovery of key factors influencing the creation of networks and co-operation would be an important empirical basis for defining effective planning strategies for cities.

Acknowledgements

Parts of this research were done within the POLYCE (Metropolisation and Polycentric Development in Central Europe) project, which was conducted within the framework of the ESPON 2013 Programme. An earlier version of the paper was presented at the Warsaw Regional Forum 2011. The authors would like to thank three anonymous referees for their comments, which were gratefully acknowledged as an important source of improvements. Of course, the responsibility for the arguments presented remains with the authors.

Editors' note:
Unless otherwise stated, the sources of tables and figures are the author(s), on the basis of their own research.

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Article first received • September 2012
Article accepted • July 2013