Polycentricity, Integration and Performance: does stronger integration between cities in Polycentric Urban Regions improve performance?

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A quarter of the European population lives in 'Polycentric Urban Regions' (PURs): clusters of historically and administratively distinct but proximate and well-connected cities of relatively similar size. This paper explores whether tighter integration can increase agglomeration benefits at the PUR-level. We provide the first comprehensive list of European PURs (117 in total), establish their level of functional, institutional and cultural integration and measure whether this affects their performance. 'Performance' is defined as the extent to which agglomeration economies have developed, proxied by the presence of metropolitan functions. In this first-ever cross-sectional analysis of PURs we find that while there is evidence for all dimensions of integration having a positive effect, particularly functional integration has great significance. Regarding institutional integration, it appears that having some form of metropolitan cooperation is more important than its exact shape. Theoretically, our results substantiate the assumption that networks may substitute for proximity.

Keywords: urban systems; urbanisation economies; transportation; metropolitan governance; Europe

JEL-codes: R11, R12, R14, R40, R58

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1. Introduction

The concentration of people and firms in cities and metropolitan areas has fascinated scholars for a long time. Such agglomerative processes generally rely on the wide-ranging benefits associated with the close proximity of people and businesses, which have been categorized in various ways (e.g. Parr, 2002; Duranton and Puga, 2004). A particularly widespread distinction in many empirical works is between urbanisation and localisation economies (Isard, 1960). A localisation economy implies returns of scale that arise from having many firms of the same industry located in cities. In contrast, urbanisation economies are the benefits obtained from large and, as Jacobs (1969) has stressed, diverse cities. These include access to knowledge and information flows between industries, a diversified and specialised labour market, collective infrastructure, specialised business services and consumer amenities.

The extent to which urbanisation economies develop has often been associated with 'size' or 'density', and many studies have shown that larger and denser cities perform better in terms of labour productivity and the presence of an urban wage premium. A doubling of city size or local activity is typically associated with a productivity increase from about 3 to 7-8% (Rosenthal and Strange, 2004; Combes and Gobillon, 2015), and a meta-analysis by Melo et al. (2009) found an average elasticity of 5.8% and a median value of 4.1%, although these effects vary across sectors and countries and depend on methodological modelling choices. Hence, the

agglomeration benefits of large cities are considered a driver of growth and prosperity, leading many local governments to adopt population growth strategies to provide their citizens and firms with more urbanisation economies, thus entering what is believed to be an upward cycle of economic growth.

Yet, this reasoning must be questioned. Camagni et al. (2016) argue that further urbanization in large megacities is not the key to welfare increases, especially in recent years. While larger cities have higher productivity, urban growth does not necessarily imply increases in productivity. In addition, Meijers et al. (2016) find that the presence of important metropolitan functions in the domains of firms, international institutions and science are today more dependent on network embeddedness of cities than on size. This is in line with the more general proposition that network economies may substitute for agglomeration economies (Johansson and Quigley, 2003). Glaeser et al. (2016) point out the presence of historical and institutional barriers limiting opportunities for growth in Europe's historic larger cities. Given the inelasticity of housing supply, there are good reasons to prefer the development of a network of smaller cities over the rise of megacities.

Indeed, a glance at the map of Europe shows an urban system based on quite proximate small and medium-sized cities (Dijkstra et al., 2013). This makes the strengthening of networks between such cities a possible alternative to further concentration in order to enhance the presence of agglomeration economies (although a term like 'urban network externalities' would do more justice to their geography in that case; see Burger and Meijers, 2016). Such clusters of historically and administratively distinct but proximate and well-connected cities have been identified as 'polycentric urban regions' (PURs) (amongst a variety of other, related designations),

and have given rise to a substantial literature on the topic (see Van Meeteren et al., 2015; Danielzyk et al., 2016, for recent overviews).

PURs have become the object of many development strategies (Kauffmann, 2016; Meijers et al., 2014) that aim to increase their competitiveness by organising agglomeration economies on the level of the network of cities. However, findings show that 'summing small cities does not make a large city' (Meijers, 2008:2323), as such regions cannot provide a level of agglomeration benefits commensurate with the aggregated size of their cities: neither in terms of cultural, leisure and sports amenities (ibid.) and specialised retail (Burger et al., 2014a), nor in terms of urbanisation economies in general (Brezzi and Veneri, 2015; Veneri and Burgalassi, 2012; Meijers and Burger, 2010). Simply put, two close-by cities of half a million cannot organise the same level of agglomeration benefits as a single city of one million. PURs 'lack the critical mass of large cities with agglomeration economies' (Lambooy, 1998:459). This seems to confirm Parr's assertion (2004) that travel, commodity and knowledge flows do not circulate as easily as in a single large city.

Yet, there are differences in performance between PURs which demand an explanation: some are better able to exploit their combined urban mass than others. This paper explores one important hypothesis that may explain such divergence, namely the extent to which the constituent cities in a PUR are integrated and interact. Interaction is at the heart of urbanisation economies; it is needed to 'share', 'match' and 'learn' (Duranton and Puga, 2004). The obvious hypothesis is that those cities that are physically separate, but strongly functionally, culturally and institutionally knit together, resemble more single large agglomerations, and as such may be able to achieve higher levels of agglomeration benefits. Empirically validating this widespread but unsubstantiated assumption would not just provide relevant input for the strategic

development of PURs, but also concretise the theoretical assumption that networks may substitute for proximity (Johansson and Quigley, 2003). So, the research question guiding this paper is: *does stronger integration between cities in Polycentric Urban Regions enable them to organize more urbanisation economies?*

So far, case studies of particular PURs have been the most common approach, while others have adopted a quantitative modelling approach by measuring the level of mono/polycentricity in functional or administrative regions (Brezzi and Veneri, 2015; Vasanen, 2012; Veneri and Burgalassi, 2012; Meijers and Burger, 2010). This paper will only focus on those regions that can be considered polycentric from a morphological perspective, irrespective of administrative borders and of whether they have been previously identified as coherent metropolitan entities (since this is the focus of our research interest). As such, the paper provides the first objective identification of all PURs in Europe. Exploring the level of integration of over 100 European PURs is challenging from the data point of view and cannot provide the in-depth detail of case studies. What it does allow, however, is to apply a consistent quantitative approach to sketch a broad picture of how polycentricity, integration and performance relate.

Section 2 reviews the literature on the relations between integration in PURs and their economic performance. Section 3 is a necessarily lengthy section describing the research approach, including the identification of PURs, the measurement of their performance, as well as the measurements regarding different forms of integration. The ordered logit models linking these elements will be presented and discussed in section 4. Section 5 concludes and discusses policy implications of the findings.

2. Linking integration to performance

The case for integrating distinctive, but complementary and inter-related components into a cohesive system has been made in many fields where the joint weight, mutual oversight and coordinated effort of actors was believed to be more conducive to prosperity than loose and fragmented efforts by individual parties. Most prominently perhaps, the European Union itself was built on this premise, but integration has also been promoted in the inter-organization literature, not for the purpose of centralization and homogenisation, but rather for optimal complementarity and responsiveness between the components of a system (Barki and Pinsonneault, 2005). The story is not very different for cities constituting the anchors of PURs. The emerging hypothesis is that the more PURs become integrated, the more they will resemble single large agglomerations, and therefore they can expect a comparable level of urbanisation economies for a similar aggregated size. In a sense, what can be added to a PUR by each of the three aspects of integration covered in this paper – functional, institutional, cultural – addresses the disadvantages that they typically have in that respect. Earlier research provides indications about why such integration between cities is important to performance.

Existing literature highlights the benefits of functional integration between cities in PURs mainly by stressing the negative consequences of not operating as a cohesive urban system. Parr (2004, p. 236) argues that "some of the advantages of urban size stem from the nature of the metropolitan environment", whose characteristics, he adds, include density, cosmopolitanism, good infrastructure and diverse spaces allowing unplanned interaction. However, PURs are often no more than 'disjointed sets of medium-sized cities' (Lambregts, 2006), whose fragmentation hampers the emergence

of such a metropolitan environment and an efficient functioning of housing and labour markets at their aggregate scale. According to Jenks et al. (2008), polycentric forms seem to intensify fragmentation rather than minimize it, making efficient and affordable transport connections between cities essential to avoid its negative consequences. Van Oort et al. (2010) stress the economic importance of functional integration and urban complementarities in PURs, similarly to Pred (1977), who had argued that urban networks enhance performance through expanded market potential, increased knowledge inputs, enhanced infrastructure provision and added sub-contracting possibilities. Jones et al. (2009) have shown patterns of a generalised presence of productive firms, skilled workforce and higher quality housing in urban regions with more complementary links, in opposition to greater contrasts between high and low productivity firms, higher and lower skilled workforce and higher and lower quality housing in places lacking such linkages. Addressing the PUR-related concept of 'megaregions', Sassen (2007) considers the advantages of a 'single economic space' containing the variety of complementary agglomeration economies and geographic settings needed by our complex economies. Indeed, functions, activities and opportunities in PURs tend to be spread throughout its cities rather than concentrated in a single node. Such complementarities are considered the key trigger of demand for transportation, which in turn promotes further interaction, in Ullman's classical formulation (1956). Recent research has therefore argued that connections promoting functional integration *within* PURs can be even more important for economic performance than long-distance connections *between* different PURs (Sweeney, 2016), as the former work to maximize the benefits of the interdependent relations of the constituent cities.

Partly to ensure they are not overlooked in the necessary investments towards functional integration, smaller, nearby cities are also joining forces via institutional integration (a metropolitan government, municipal mergers or inter-municipal collaboration) to become a demographically, economically and politically more relevant actor, acquiring a louder voice in negotiations with higher levels of government and influencing policy in their interests. Another purpose is to increase their intra-regional organising capacity, i.e. to share more efficiently existing resources, coordinate decisions in issues affecting the larger scale, such as infrastructure and land use, and foster complementarity between centres rather than redundant competition, all of which can create a favourable investment environment and increase economic productivity. Ahrend et al. (2015) have shown that city regions with more fragmented governance structures have indeed lower levels of productivity. Institutional integration can therefore minimize the fragmentation of PURs, and, again, make them resemble more large agglomerations governed by a single institutional body.

A history of cooperation between cities (institutional integration) and enhanced mobility (functional integration) are likely to shape what has been called a 'metropolitan identity', an upscaling of spatial attachments of citizens (Kübler, 2016), formerly reserved to individual cities or neighbourhoods. This is not just a 'functional' awareness of an economically interrelated space, but implies the development of emotional ties and a sense of shared identity – in other words, a form of cultural integration. This approximation can make institutional integration more acceptable for citizens (Kübler, 2016) and allows the emergence of tighter and more durable networks of activity at that scale (Nelles, 2013), as common problems, objectives and interests become more evident across the region and are more easily agreed upon. Conversely, PURs lacking cultural proximity may remain politically more fragmented,

less willing to adhere to a common strategy and develop autonomous and competing understandings of their territory, hampering the emergence of potential benefits of agglomeration at that scale. Van Houtum (1998) has demonstrated that 'mental distance', expressed by cultural contrasts between neighbouring partners, has indeed a negative effect on the likelihood of building economic relations and the trade-inhibiting effect of 'cultural distance' has been established many times (e.g. Tadesse and White, 2010).

There are several aspects in which functional, institutional and cultural integration can help PURs reproduce the apparent advantages that allow large cities to reap the benefits of agglomeration. These dimensions of integration are interrelated and may potentially enhance or restrict each other. The remainder of this paper explores whether the relation between greater integration and stronger urbanisation economies can be empirically substantiated across European PURs and whether some dimensions of the process are more relevant than others.

3. Research approach

3.1 Identifying Polycentric Urban Regions

Despite the longstanding interest in the topic, there is no comprehensive list of European PURs, probably due to conceptual fuzziness and discussion over whether polycentricity refers just to morphological aspects or should also incorporate relational aspects between the centres making up the PUR (e.g. Green, 2007). Since our interest here is whether or not these relational aspects matter for their performance, we use a morphological perspective, aiming to identify those regions that are characterised by a balanced size distribution of their urban agglomerations, with

greater balance equated with higher levels of polycentricity. There are several ways to measure this, such as looking at the slope of the regression line that best fits the rank-size distribution (e.g. ESPON 1.1.1), or measuring primacy (e.g. ESPON 1.4.3). Since the former is not easy to calculate and involves some arbitrary decisions regarding the number of cities considered, while the focus of the latter on the primacy of a single city cannot account for size distributions among the remaining cities, we introduce the Herfindahl (or Herfindahl-Hirschmann) index as a good, simple and novel measure to calculate polycentricity. This index is most commonly applied as a measure of competition in the framework of antitrust laws preventing the rise of monopolies from firm mergers. As such, measuring 'dominance' is its essence, which parallels nicely with the basic idea that polycentricity is about the lack of dominance of a single city. It is computed as:

$$H = \sum_{i=1}^{N} s_i^2$$

where s_i is the population share of city i in the total population of all cities in the region, and N is the number of cities in the region. Scores range from $1/N$ to 1; the lower, the more polycentric.

To clarify the delimitations of 'city' and 'region', we rely on ESPON-programme findings. 'City' limits are not defined by administrative boundaries, but include all municipalities that form a contiguous built-up area, defined as 'morphological urban areas' (MUAs) by the ESPON 1.4.3 project (IGEAT et al., 2007). The classification only accounts for PURs that contain at least two such agglomerations, with a minimum of 40 thousand inhabitants.

For 'region', several delimitations are adopted. This includes 'Functional Urban Areas', gathering MUAs and their hinterlands as defined by commuter basins. As these are defined with a monocentric perspective in mind (city-hinterland), we also consider a regional delimitation called 'polyFUA', constructed when contiguous FUAs are merged based on city sizes and distances between them. For instance, large cities (>500 thousand) less than 60 km apart with contiguous labour basins were merged (for smaller cities, this threshold was set at 30 km). These delimitations were also provided by ESPON 1.4.3, that also defined a 'suprapolyFUA' to capture two classic examples of PURs, the RheinRuhr and the Randstad. Finally, a third delimitation for the 'region' is provided by the definition in ESPON 1.1.1 of functionally less integrated areas, called 'Potential Integration Areas' (PIAs). These are constructed by merging FUAs whose 45-minute isochrones overlap by at least 33%. Since the purpose is to measure the effect of (functional) integration on the performance of PURs, it is essential to include PIAs to prevent the bias of only selecting urban regions that are substantially integrated already. To control for excessively large PIAs, there are some additional criteria: all core cities of FUAs should be within 60 minutes travel time from each other and at least two within 45 minutes.

The last step is determining the cut-off point of the Herfindahl-index. This was pragmatically done using common sense (usual suspects should be included, while obviously monocentric urban regions should not) and determined to be 0.56. Annex 1 presents the full list of 117 PURs in Europe, indicating the countries involved, the number of cities (MUAs) included, their population and their level of polycentricity. The most polycentric region in Europe is the Randstad (Amsterdam-Rotterdam-The Hague-Utrecht and 35 other distinct cities), while the bipolar Skien-Larvik region in Norway just met the polycentricity threshold. PURs come in many different sizes and

can be found in almost all European countries[1] (some of them are cross-border). Italy contains the greater number of PURs (#18), followed by Germany (#14). The Randstad and the RheinRuhr contain the greater number of constituent cities (#39). Almost 122 million Europeans live in PURs, which corresponds to 25% of the population of the EU (+Norway and Switzerland).

3.2 Measuring the performance of PURs

The performance of a PUR is measured as the extent to which it is able to organise a level of agglomeration benefits commensurate with the aggregated size of the constituent cities. In other words, how much are two nearby cities of half a million people each able to jointly organise the agglomeration benefits one would expect to find in a single city of one million? As a proxy for agglomeration benefits, we use the presence of metropolitan functions, adapted from a database compiled by the German Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR, 2011). This database includes functions in the domains of 'Science' (including the presence of major universities and international research organisations); 'Economy' (including headquarters of Fortune-500 firms measured by turnover rate and staff size, advanced producer services, banks, and exhibition fairs); 'Culture' (subdivided into cultural events: music concerts, art fairs and film festivals; and cultural venues: theatres, opera houses, galleries and museums); and 'Sports' (including stadiums, Olympic games venues, and major sports events). These domains add up to an overall index of metropolitan functions. Data on individual functions were gathered for the 2004-2009

[1] Exceptions being Cyprus, Ireland, Malta, Finland, Slovenia and the Baltic states. ESPON data is not available for countries outside of the European Union (+Norway and Switzerland).

period, with the majority corresponding to 2008. For an extensive account about the data, please consult BBSR (2011).

Using a similar database, it was previously established that size is a very strong predictor of the presence of those metropolitan functions, but that a number of other control variables need to be considered as well, such as tourism, GDP per capita and country dummies (Meijers and Burger, forthcoming), network connectivity (Meijers et al., 2016) and capital city status (Cardoso and Meijers, 2016). Indicators for most of these controls come from the BBSR database. Network connectivity is assessed by calculating an index of air transport connectivity based on 'passenger volume', 'number of connections within Europe' and 'number of intercontinental connections', and by measuring the embeddedness of cities in international political networks from the presence of UN offices, EU institutions and NGOs. Tourism was measured by a combination of the presence of UNESCO world heritage sites and the attractiveness ranking of places according to the Michelin tourist guides. Table 1 provides the results of applying this model to a database of all cities (MUAs) in Europe, explaining the presence of metropolitan functions. As some cases do not contain any metropolitan functions at all, zero-inflated beta regression is used. This includes a logistic regression model for whether or not the proportion of metropolitan functions in a city equals zero, and a beta regression model for the proportions between 0 and 1.

Table 1. Zero-inflated beta regression on metropolitan functions in single European cities (MUAs).

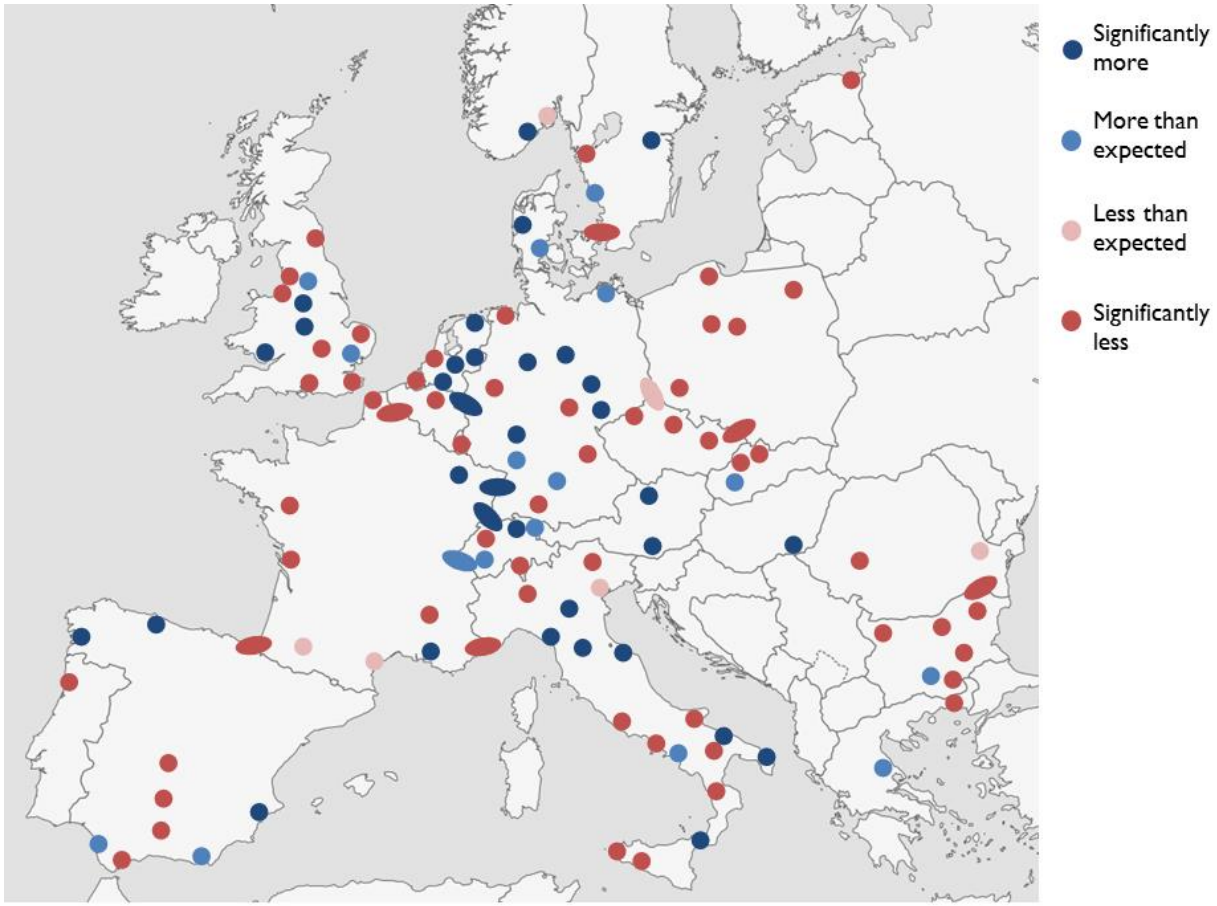
Model 1	**Coefficients**
Proportion part	
Population size city (MUA)	.00086 (.00014)**
Population size hinterland (region-MUA)	.00017 (.00007)*
Capital city (dummy)	.42061 (.24008)
GDP per capita	.02477 (.00481)**
International political network embeddedness	1.05283 (.57242)
Network connectivity (airport)	-1.50303 (.43837)**
Tourism	1.74959 (.25878)**
Country dummies	YES
Zero-inflated part	
Population size city (MUA)	-.02389 (.00291)**
Population size hinterland (region-MUA)	.00021 (.00017)
Capital city (dummy)	-6.53248 (6.61642)
GDP per capita	-.02901 (.01063)**
International political network embeddedness	-12.24583 (63.18845)
Network connectivity (airport)	.104825 (.83187)
Tourism	-4.49373 (.88874)**
Country dummies	YES
Number of observations	1,947
ln phi	4.00166 (.10442)**

Robust standard errors in parentheses. ** p <0.01; * p < 0.05.

The primary relevance of the beta regression equation presented in Table 1 is that it provides a very accurate prediction of the level of metropolitan functions (as proxy for agglomeration benefits) that we can find in *single* cities in Europe. The next step in the approach was to apply this regression equation derived for single cities to the 117 PURs, to see to what extent they host the metropolitan functions one would expect to find if they were single agglomerations rather than a collection of distinct cities. For this, we aggregated the scores of the cities in each PUR, calculated their expected level of metropolitan functions and compared this to their actual level. The proportion part is mainly relevant since we did not predict any of our PURs to have no metropolitan

functions (the zero-inflated part). This allowed the classification of 117 PURs into four categories, ordered according to performance: PURs that have significantly (p<.05) less metropolitan functions than we would expect; PURs that also have less than predicted metropolitan functions, but not significantly so; PURs that have more metropolitan functions than expected; and PURs having significantly more metropolitan functions (hence agglomeration benefits) than expected. As can be read from Figure 1, performance levels of PURs vary within most countries, and no clear spatial pattern can be distinguished, with the exception of somewhat weaker performance levels in Eastern Europe.

Figure 1. Performance levels of PURs across Europe.



3.3 Measuring integration

To explore whether this performance can be explained by the level of integration between cities, we identify and measure multiple dimensions of integration: functional, institutional and cultural (Table 2). These three dimensions are derived from the widely followed conceptual framework provided by Kloosterman and Musterd (2001). The requirement to use regionally specific data with European-wide coverage that is available at the city level comes at a cost, as this does not allow to capture the full complexity of each of the three dimensions, as for instance explained for functional integration in Burger et al., (2014b), for institutional integration in Spaans and Zonneveld (2016) and Cardoso (2016), or even for cultural integration in Vainikka (2015), who discusses how regions are culturally constructed. However, it can be argued that the indicators below capture some of their essence and have the advantage of being obtainable for all PURs across Europe, although sometimes only in a laborious way.

Functional integration relies on indicators that measure the ease and efficiency of moving between cities using private and public transportation, as well as the frequency of public transit. The rationale is that the criss-cross pattern of movements between cities is facilitated by efficient infrastructure, and at the same time increases demand for such efficient infrastructure, so integration and efficient infrastructure seem intertwined. The frequency of public transit more directly measures actual travel demand for transit between cities.

Institutional integration is measured by indicators reflecting the level of cooperation of local governments. This is assessed by the existence of a metropolitan authority or partnership, the number of years it has been active, and how it is shaped

in terms of powers and autonomy. To be considered, such entities had to cover at least 50% of the population of a PUR; administrative or statistical divisions, such as provinces, were not considered.

The measurements of cultural integration focus on whether cities in a PUR are culturally proximate, as reflected by the political colour of their municipal cabinets. Recent studies (Hoffmann-Martinot and Sellers, 2005) have stressed the barriers caused by gaps of political orientations (e.g. left-leaning core cities vs. conservative suburbs), which force municipalities to respond to very different electorates. More compatible political preferences of the majority of the population indicate less contrasting sets of aspirations, and greater cultural integration. Another cultural barrier is language. We assume that if language barriers divide PURs, this will negatively affect their performance. This often occurs in cross-border PURs, but also in the central Belgian urban network known as 'Flemish Diamond'.

Table 2. Measurement of integration in polycentric urban regions.

Variable	Measurement	Specification	Source
Functional coherence			
Efficient road connections	Distance (km) covered per minute between city centres (average per connection between every two city centres in a PUR)	Higher= more efficient	Google Maps
Efficient rail connections	Distance (as the crow flies, km) covered per minute between city centres (average per connection between every two city centres in a PUR).	Higher= more efficient	Google Maps and Deutsche Bahn
Frequency train connections	Average number of trains between each pair of cities in a PUR between 8:00 and 20:00.	Higher= higher frequency	Deutsche Bahn
Institutional coherence			
Presence of a metropolitan body	Existence of an organisation, institution or association dedicated to metropolitan cooperation covering more than 50% of the PUR	YES= more integrated	Internet searches
Number of years active	Number of years that metropolitan entity has been active	Higher= more integrated	Internet searches
Type of partnership	Categorisation of the type of metropolitan entity: 1- Informal agreement towards cooperation 2- Active networks including municipalities and other partners (e.g. British LEPs) 3- Effective associations of municipalities with powers and budget (e.g. French intercommunal structures) 4- (Elected) metropolitan authorities (e.g. English Combined Authorities)	Higher= more integrated	Internet searches
Cultural coherence			
Political preference homogeneity	Political colour of mayors of the cities in the PUR. Measured as a Herfindahl-index based on shares of population per political party. Political parties in cross-border regions are first aggregated to corresponding parties in European Parliament.	Higher= more integrated	Websites, overviews per country, election databases.
Language homogeneity	Dummy variable, where 1 means the absence of language barriers and 0 the presence of such barriers. 0 is given only if at least 10% of the PUR population speaks a different language.	Higher= more integrated	Based on 'Languages of Europe' map

The individual indicators in Table 2 have also been aggregated, after normalizing, to overall indexes of functional, institutional and cultural integration, with higher scores representing more integration. The next section explores whether these levels of integration affect the performance of PURs. Descriptive statistics are provided in Table 3, and correlation matrices in Table 4 and Table 5 (indices) respectively. We reflect on

the multicollinearity between 'presence of a metropolitan body' and 'type of partnership' below.

Table 3. Descriptive statistics.

	Mean	Standard deviation	Minimum	Maximum
Efficient road connections	1.12	.20	.30	1.59
Efficient rail connections	.65	.41	0	2.63
Frequency train connections	23.56	20.62	0	98
Presence of a metropolitan body	.48	.50	0	1
Number of years active	4.74	7.79	0	1
Type of partnership	1.18	1.36	0	1
Political preference homogeneity	.60	.21	.31	1
Language homogeneity	.86	.35	0	1

Table 4. Correlation matrix.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Efficient road connections	1.00							
(2) Efficient rail connections	0.20*	1.00						
(3) Frequency train connections	0.13	.10	1.00					
(4) Presence of a metropolitan body	0.08	-.04	.44**	1.00				
(5) Number of years active	0.19*	.04	.34**	.64**	1.00			
(6) Type of partnership	.008	-.03	.47**	.91**	.58**	1.00		
(7) Political preference homogeneity	.00	.11	.09	.03	-.02	.12	1.00	
(8) Language homogeneity	.02	.11	-.04	-.12	-.13	-.06	.14	1.00

**p <.01, * p <.05

Table 5. Correlation matrix indices.

	(1)	(2)	(3)
Functional integration index	1.00		
Institutional integration index	.10	1.00	
Cultural integration index	.30**	-.04	1.00

**p <.01, * p <.05

4. Results

4.1 Individual dimensions of integration

First we explore whether each type of integration (functional, institutional, cultural) has a direct relationship with performance. Then we consider their combined effect, and finally, we explore whether these three types of interaction positively influence each other. Table 6 shows the results of ordered logit models exploring how the different variables capturing functional integration affect the performance of PURs, as measured by the extent to which agglomeration benefits in the form of metropolitan functions are present. The table considers individual factors (model 2-4), and then the effect of their combination (models 5 and 6).

Table 6. Ordered logistic regression results showing the influence of functional integration on the performance of polycentric urban regions.

	Model 2 Performance	Model 3 Performance	Model 4 Performance	Model 5 Performance	Model 6 Performance
Efficient road connections	1.204 (.901)			.609 (.957)	
Efficient rail connections		.840 (.440)#		.687 (.449)	
Frequency train connections			.028 (.009)**	.027 (.009)**	
Functional integration index					.931 (.293)**
Number of observations	117	117	117	117	117
LR chi^2	1.83	3.87*	10.13**	13.46**	11.01**
Pseudo R^2	.007	.0147	.0386	.0512	.0419

Standard errors in parentheses. **p <0.01; *p < 0.05, # p < 0.10.

Table 6 shows a positive and significant relationship between functional integration and performance in PURs: the more functionally integrated, the more a PUR is able to organise agglomeration benefits (model 6). Of the three individual factors, only the frequency of train connections between the cities constituting a PUR is significant at

the 1% level. It could be argued that this variable captures the essence of functional integration more directly (reflecting actual demand/flows between places) than the efficiency of the road and rail connections. A significant Likelihood Ratio (LR) chi^2 test (as in model 3-6) establishes that at least one of the variables' regression coefficient is not equal to zero. McFadden's pseudo R^2 cannot be easily compared to R^2 in OLS, but allows mainly to compare between the models presented here.

Table 7 presents the results for the institutional integration variables, again showing results for individual indicators (models 7-9) and their combined effect (models 10-11).

Table 7. Ordered logistic regression results showing the influence of institutional integration on the performance of polycentric urban regions.

	Model 7 Performance	Model 8 Performance	Model 9 Performance	Model 10 Performance	Model 11 Performance
Presence of a metropolitan body	.816 (.358)*			1.322 (.872)	
Number of years active		.039 (.022)#		.010 (.029)	
Type of partnership			.222 (.130)#	-.249 (.303)	
Cooperation index					.423 (.198)*
Number of observations	117	117	117	117	117
LR chi^2	5.29*	3.04#	2.91#	6.11	4.60*
Pseudo R^2	0.020	0.012	0.011	0.023	0.018

Standard errors in parentheses. $^{**}p < 0.01$; $^{*}p < 0.05$, $\# p < 0.10$.

Although 'presence of a metropolitan body' and 'type of partnership' were clearly correlated (see Table 4), making the results of model 10 less relevant, it is still important to show results for both, as it can be concluded that having a working metropolitan body (model 7) seems more important than the exact form of the partnership (model 9), which contributes less to performance. There are some indications that longer lasting cooperation is associated with better performance, but

this is only significant at the $p<.10$ level. Taken together, more institutional integration between cities in PURs has a positive effect on its performance (model 11).

As for cultural integration (Table 8), this dimension of integration does not seem relevant for the performance of PURs. The indicators as well as the overall index for cultural integration are not significant.

Table 8. Ordered logistic regression results showing the influence of institutional integration on the performance of polycentric urban regions.

	Model 12 Performance	Model 13 Performance	Model 14 Performance	Model 15 Performance
Political preference homogeneity	1.304 (.813)		1.226 (.824)	
Language homogeneity		.439 (.540)	.310 (.550)	
Cultural integration index				.379 (.239)
Number of observations	117	117	117	117
LR chi^2	2.58	0.68	2.90	2.61
Pseudo R^2	0.010	0.003	0.011	0.010

Standard errors in parentheses. $^{**}p<0.01$; $^{*}p<0.05$, $\#\ p<0.10$.

4.2 Aggregate dimensions of integration

Table 9 presents the effect of the three aggregate indices of integration simultaneously, also when adding three additional control variables (model 17). As controls we added the (urban) size of a PUR, as well as a dummy indicating whether a PUR is located in Eastern Europe or not, not just because our map (Figure 1) suggests differences in performance levels, but also because literature suggests contrasting urban dynamics (e.g. Dijkstra et al., 2013). In addition, we add a variable indicating whether a PUR is crossborder. Many contributions have stressed the challenging conditions of the various dimensions of integration in cross-border metropolitan regions (e.g. Sohn and

Reitel, 2016; Nelles and Durand, 2014). As for some PURs only a small part of their territory is cross-border, we developed an indicator that reflects the degree of 'crossborder-ness', calculated as (1-) the Herfindahl index based on shares of PUR population in the different countries. Table 9 also explores whether there are positive feedbacks between the various forms of integration by adding interaction terms (model 18-20). Do we find evidence that, for example, stronger functional integration results in more cultural or institutional integration?

Table 9. Ordered logistic regression results showing the influence of integration on the performance of polycentric urban regions.

	Model 16 Performance	Model 17 Performance	Model 18 Performance	Model 19 Performance	Model 20 Performance
Functional integration (index)	.782 (.304)**	.771 (.336)*	.776 (.338)*	.769 (.336)*	.785 (.339)*
Institutional integration (index)	.302 (.211)	.339 (.237)	.363 (.242)	.334 (.239)	.348 (.238)
Cultural integration (index)	.349 (.250)	.530 (.316)#	.546 (.319)#	.525 (.320)	.523 (.318)
PUR size		-.00036 (.00021)#	-.00034 (.00021)	-.00035 (.00021)#	-.00036 (.00021)#
Eastern Europe dummy		-1.151 (.636)#	-1097 (.646)#	-1.156 (.637)*	-1.146 (.636)*
Crossborder (degree)		2.302 (1.485)	2.261 (1.488)	2.251 (1.546)	2.141 (1.536)
Interaction Functional X Institutional Integration			-.195 (.352)		
Interaction Functional X Cultural Integration				.051 (.430)	
Interaction Institutional X Cultural integration					-.124 (.301)
Number of observations	117	117	117	117	117
LR chi^2	14.71**	26.83**	27.04**	26.85**	25.07**
Pseudo R^2	0.056	.102	.103	.102	.095

Standard errors in parentheses. **p <0.01; *p < 0.05, # p < 0.10. For the models presenting interactions (model 18-20), all variables were mean centred first (except for the Eastern Europe dummy).

Taken together, the three indices of integration are able to explain the performance of PURs better than individually, as is evidenced by the rising Pseudo R^2 and Likelihood Ratio of the chi^2. The significant positive effect of functional integration is repeatedly shown in the models of Table 9. Counter to model 11, the institutional integration index is not significant at the $p< 0.05$ level in these models. Interestingly, the cultural integration index becomes significant after adding controls (albeit at the $p< 0.10$ level), providing a clear hint that more cultural integration between cities also fosters the development of agglomeration economies in the form of metropolitan functions (model 17).

The addition of three controls adds to the explanatory power of the model as a whole. PURs located in Eastern Europe generally perform less well than PURs located elsewhere in Europe (model 17). Regarding the size of PURs, the direction of the relationship suggests that it is harder for larger PURs to exploit their critical mass than for smaller ones. The complexities inherent to cross-border PURs do not translate into their weaker performance, the positive sign even suggests the opposite.

A number of models were conducted to explore whether the different dimensions of integration had a different impact on large or small PURs, or between PURs located in different parts of Europe (Eastern Europe), or in cross-border PURs, but none of the interactions between 'PUR size', 'Eastern Europe dummy' or 'Cross-border (degree)' on the one hand, and the three types of integration, on the other, were significant (models not reported). This suggests that the relationships found between integration and performance apply to all PURs, regardless of size, location in Europe or being cross-border.

Models 18-20 report interactions between the different dimensions of integration; in other words, are for instance regions that are functionally *and* culturally

more integrated performing better? The lack of significance of the interaction term in model 19 suggests that this is not the case, and the same holds for the interactions Functional x Institutional and Institutional x Cultural. In other words, no quantitative evidence was found for a kind of upward spiral of integration, in which different dimensions of integration positively enhance each other.

5. Discussion and conclusion

This paper explored whether the level of integration between cities making up a polycentric urban region (PUR) influences the PUR's performance. The latter was proxied by the extent to which these PURs had a level of metropolitan functions one would expect to find if they were functioning as a single city. The hypothesis was that stronger integration between cities in a PUR increases the presence of metropolitan functions, hence substantiating the theoretical assumption that networks can substitute for proximity when it comes to organising agglomeration benefits. Three forms of integration (functional, institutional and cultural) were conceptualised and their theoretical positive association with performance was discussed. Exploring levels of integration and performance in all 117 European PURs, we established that:

- The stronger the cities in PURs are functionally integrated, the better their performance in the sense of organising agglomeration economies;
- Institutional integration, or metropolitan governance, has a positive effect on the performance of PURs, although the effect is smaller than for functional integration. Most important is that there is some form of metropolitan cooperation, but its exact shape and power/autonomy seem of secondary importance. There is some indication that the duration of cooperation plays a

role, with longer lasting networks somewhat associated with better performance;

- Several models hint at cultural integration also positively affecting the performance of PURs.
- While conceptually the different forms of integration seem to positively enhance each other, this could not be empirically established.
- Although PURs come in a wide variety of sizes and are spread all over Europe, there is no evidence that the link between integration and performance is different according to the size or the location of the PUR or to being cross-border.

Translating these findings into policy recommendations is rather straightforward. And, given that so many people in Europe live in PURs, it becomes urgent. The main challenge in PURs is to move from fragmentation to integration. PURs need to become integrated functional entities to reap the benefits of their aggregated size as a fully-fledged metropolitan environment. Lack of such coherence means weaker performance. As such, actions aimed at fostering this integration pay off. This goes beyond the obviously required investments in connecting infrastructure and inter-urban public transit. What is needed is a larger process of region-building also referred to as 'metropolisation', in which the economic, functional, administrative and socio-spatial qualities and features once attributed to the 'city' are reconstructed by citizens, firms and institutions at the scale of the PUR. Our findings also provide important input to many national debates on whether a further concentration of investment and urban development in capital city-regions is the most desirable, suggesting that

investment in the metropolisation of PURs is a viable and profitable alternative to such concentration.

An advantage of the quantitative, cross-sectional approach followed here is the detection of general principles applying to the functioning of PURs. The novel, methodologically consistent listing of PURs presented in this paper opens up opportunities for more comparative research on related issues and can hopefully inspire others to pursue further pathways to explain in greater detail the inner workings of PURs and their sometimes surprising contrasts. Promising lines of inquiry could be, for instance, the relevance for performance of complementarities between cities versus concentration; the use of other proxies for performance, checking whether the relative importance of functional, institutional and cultural integration changes; and applying other indicators to measure these three dimensions of integration, perhaps better adapted to particular contexts. Finally, the addition of a time dimension to understand the evolution of PURs also needs to be part of a future research agenda.

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Annex 1. Polycentric urban regions in Europe.

Country	Polycentric urban region	Polycentricity (Herfindahl-index)	# MUAs included	Population size* (x1000)	Type of region
AT	Linz-Wels-Steyr-Amstetten	0,48	4	985	PIA
AT	Klagenfurt-Villach-Wolfsberg	0,40	3	483	PIA
AT/DE/CH	Sankt Gallen-Bregenz	0,15	11	780	PIA
BE	Flemish Diamond	0,33	10	5.103	polyFUA
BG	Plovdiv-Pazardzhik-Asenovgrad	0,48	3	612	PIA
BG	Sliven-Yambol	0,53	2	220	PIA
BG	Haskovo-Kardzhali	0,52	2	170	PIA
BG	Shumen-Targovishte	0,53	2	170	PIA
BG	Veliko Tarnovo-Gabrovo	0,50	2	166	PIA
BG	Vraca-Montana	0,51	2	148	PIA
BG/RO	Calarasi-Silistra	0,51	2	139	PIA
CH	Zürich	0,48	10	1.615	FUA
CH	Bern-Neuchâtel-Biel-Thun	0,21	9	859	PIA
CH	Lausanne-Vevey-Yverdon-Monthey	0,54	4	439	PIA
CH	Locarno-Bellinzona	0,50	2	99	FUA
CH/FR	Genève-Annemasse-Annecy-Cluses	0,45	4	1.200	PIA
CZ	Olomouc-Zlin-Prerov-Prostejov	0,28	4	612	PIA
CZ	Decin-Teplice-Usti nad Labem	0,27	4	495	PIA
CZ	Hradec Kralove-Pardubice	0,50	2	322	PIA
DE	Rhein-Ruhr (Cologne-Dusseldorf-Essen-Dortmund)	0,12	39	12.190	suprapoly FUA
DE	Rhein-Main	0,36	7	4.149	polyFUA
DE	Rhein-Neckar (Mannheim-Ludwigshafen-Heidelberg)	0,20	8	2.931	polyFUA
DE	Leipzig-Halle	0,52	3	1.214	polyFUA
DE	Bielefeld-Detmold	0,44	4	1.173	polyFUA
DE	Braunschweig-Wolfsburg	0,32	4	1.004	polyFUA
DE	Chemnitz-Zwickau-Aue-Greiz	0,42	4	940	PIA
DE	Erfurt-Jena-Weimar	0,23	7	853	PIA
DE	Ulm-Aalen-Heidenheim	0,34	4	683	PIA
DE	Wilhelmshaven-Emden	0,53	2	332	PIA
DE	Amberg-Weiden(Oberpfalz)	0,50	2	276	PIA
DE	Ravensburg-Kempten	0,50	2	208	PIA
DE	Stralsund-Greifswald	0,50	2	181	PIA
DE/FR	Strasbourg-Baden-Offenburg-Haguenau	0,45	6	1.048	PIA
DK	Herning-Holstebro-Skive-Ringkøbing	0,36	4	279	PIA
DK	Kolding	0,50	2	171	FUA
DK/SE	Öresund	0,49	7	2.842	polyFUA
EE	Narva-Kohtla Jarve	0,52	2	141	PIA
ES	Oviedo-Gijon-Aviles	0,28	5	844	polyFUA
ES	Alicanta-Elche	0,42	3	793	polyFUA
ES	Cadiz-Jerez-Sanlucar	0,42	3	668	PIA
ES	Vigo-Pontevedra-Vilagarcia	0,53	3	638	PIA
ES	Almeria-Roquetas-Ejido	0,46	3	322	PIA
ES	Jaen-Linares	0,55	2	264	PIA
ES	Algeciras	0,51	2	206	FUA
ES	Toledo-Aranjuez	0,54	2	147	PIA
ES	Ciudad Real-Puertollano	0,50	2	143	PIA
ES/FR	Donostia-San Sebastian-Bayonne	0,37	4	1.391	PIA

FR	Marseille-Aix-en-Provence	0,50	6	1.530	FUA
FR	Metz-Nancy-Thionville-Hagondange	0,27	5	943	PIA
FR	Dunkerque-Calais-Saint-Omer	0,44	3	486	PIA
FR	La Rochelle-Niort-Saintes-Rochefort	0,34	4	396	PIA
FR	Pau-Tarbes-Oloron-Sainte Maire	0,55	4	369	PIA
FR	Valence-Privas-Romans-Montelimar	0,42	4	313	PIA
FR	Béziers-Narbonne	0,53	2	196	PIA
FR	Cholet-La Roche sur Yon	0,50	2	172	PIA
FR/BE	Lille	0,22	15	3.115	polyFUA
FR/DE/CH	Basel-Mulhouse	0,32	6	982	polyFUA
FR/IT	Nice-Côte d'Azur-San Remo	0,27	7	1.189	PolyFUA
GR	Larisa-Volos	0,52	2	211	PIA
GR	Alexandroupolis-Komotini	0,50	2	106	PIA
HU	Szeged-Mako-Szentes-Hodmezovasarhely	0,43	4	371	PIA
IT	Napoli	0,42	10	3.714	polyFUA
IT	Venezia-Padova	0,43	3	1.401	polyFUA
IT	Firenze	0,39	6	1.090	polyFUA
IT	Parma-Reggio Emilia-Sassualo	0,31	4	675	PIA
IT	Messina-Reggio del Calabria	0,35	5	670	PIA
IT	Bari	0,51	7	584	FUA
IT	Lecce-Brindisi-Gallipoli-Nardo	0,43	4	532	PIA
IT	Ancona-Fano	0,24	6	494	PIA
IT	Trento-Bolzano	0,32	4	448	PIA
IT	La Spezia-Massa-Carrara-Viareggio	0,27	4	433	PIA
IT	Foggia-San Severo-Manfredonia	0,31	4	382	PIA
IT	Salerno	0,51	3	373	FUA
IT	Latina	0,26	5	320	FUA
IT	Cosenza-Lamezia Terme	0,53	2	313	PIA
IT	Agrigento-Caltanisetta	0,23	5	269	PIA
IT	Marsala	0,53	2	127	FUA
IT	Altamura	0,52	2	105	FUA
IT/CH	Milano	0,48	16	6.011	polyFUA
LU/BE/DE/FR	Luxembourg	0,17	9	983	polyFUA
NL	Randstad (Amsterdam-Rotterdam-The Hague-Utrecht)	0,09	39	6.787	suprapolyFUA
NL	Noord-Brabant (Eindhoven-Tilburg-Den Bosch-Breda)	0,11	17	2.083	polyFUA
NL	Groningen-Assen	0,46	3	467	PIA
NL	Middelburg-Vlissingen	0,34	3	176	FUA
NL/DE	Arnhem-Nijmegen-Apeldoorn-Wageningen	0,14	11	1.257	polyFUA
NL/DE	Enschede-Almelo	0,30	5	518	polyFUA
NL/DE/BE	Maastricht-Aachen-Heerlen-Liège	0,15	11	3.060	polyFUA
NO	Skien-Larvik	0,56	2	204	PIA
NO	Kristiansand-Arendal	0,54	2	188	PIA
PL	Gdansk-Gdynia	0,54	2	993	FUA
PL	Bydgoszcz-Torun	0,55	2	721	PIA
PL	Plock-Wloclawek	0,50	2	300	PIA
PL	Legnica-Jelenia Gora	0,50	2	256	PIA
PL	Lomza-Ostroleka	0,50	2	156	PIA
PL/CZ	Silesian-Moravian	0,34	24	5.294	polyFUA
PL/DE/CZ	Liberec-Gorlitz	0,29	3	346	PIA

PT	Porto-Braga-Guimaraes	0,43	10	2.391	PIA
RO	Galati-Braila	0,51	2	556	PIA
RO	Hunedoara-Deva	0,50	2	153	PIA
SE	Linköping-Norrköping	0,50	2	407	PIA
SE	Halmstad-Varberg-Falkenberg	0,53	3	200	PIA
SE	Trollhättan-Uddevalla	0,50	2	184	PIA
SK	Zilina-Martin	0,51	2	254	PIA
SK	Trencin-Povazska Bystrica-Banovce	0,38	3	216	PIA
SK/HU	Nitra-Trnava	0,19	7	550	PIA
UK	Leeds-Bradford	0,21	8	2.302	FUA
UK	Liverpool-Birkenhead	0,44	9	2.241	FUA
UK	Tyneside	0,47	7	1.599	polyFUA
UK	Sheffield	0,41	6	1.569	FUA
UK	Portsmouth-Southampton	0,38	6	1.547	FUA
UK	Nottingham-Derby	0,34	6	1.534	FUA
UK	Cardiff and South Wales	0,36	7	1.097	FUA
UK	Norwich-Lowestoft	0,35	5	675	PIA
UK	Ipswich-Colchester-Clacton on Sea-Felixtowe	0,37	4	538	PIA
UK	Thanet-Ashford-Canterbury-Dover	0,30	4	391	PIA
UK	Blackburn	0,52	2	391	FUA
UK	Kettering-Corby	0,50	2	140	FUA

*calculation based on IGEAT et al. (2007), except for Halmstad-Varberg-Falkenberg, for which ESPON 1.1.1 figures are used as Varberg is considered part of the Gothenburg FUA in ESPON 1.4.3.