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BEYOND POLYCENTRICITY: DOES STRONGER INTEGRATION BETWEEN CITIES IN POLYCENTRIC URBAN REGIONS IMPROVE PERFORMANCE?

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ABSTRACT
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 urbanisation 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 co-operation is more important than its exact shape. Theoretically, our results substantiate the assumption that networks may substitute for proximity.

Key words: urban systems, urbanisation economies, transportation, metropolitan governance, Europe

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 categorised in various ways (e.g. Parr 2002; Duranton & 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 per cent (Rosenthal & Strange 2004; Combes & Gobillon 2015), and a meta-analysis by Melo *et al.* (2009) found an average elasticity of 5.8 per cent and a median value of 4.1 per cent, 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 urbanisation 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 aligns with the more general proposition that network economies may substitute for agglomeration economies (Johansson & Quigley 2003). Glaeser *et al.* (2016) point out the presence of historical and institutional barriers limiting opportunities for growth in Europe's 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 an alternative to further concentration in order to enhance the presence of agglomeration economies (although terms like 'urban network externalities' or 'agglomeration externality fields' would do more justice to their geography in that case; see Burger & Meijers 2016). Such clusters of historically and administratively distinct but proximate and well-connected cities have been identified as 'polycentric urban regions' (PURs), among 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, p. 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 (Meijers 2008) and specialised retail (Burger *et al.* 2014a), nor in terms of urbanisation economies in general (Meijers & Burger 2010; Veneri & Burgalassi 2012; Brezzi & Veneri 2015). 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, p. 459). This seems to confirm Parr's (2004) assertion 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 & Puga 2004). The 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 & Quigley 2003). So, the research question guiding this paper is: does stronger integration between cities in Polycentric Urban Regions enable them to organise 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 (Meijers & Burger 2010; Vasanen 2012; Veneri & Burgalassi 2012; Brezzi & Veneri 2015). 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 comprehensive identification and precise definition of all PURs in Europe.[1] Exploring the level of integration of over 100 European PURs is challenging data-wise 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.

The following section reviews the literature on the relations between integration in PURs and their economic performance. The third section 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 the fourth section. The final section concludes and discusses policy implications of the findings.

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 co-ordinated 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-organisation literature, not for the purpose of centralisation and homogenisation, but rather for optimal complementarity and responsiveness between the components of a system (Barki & Pinsonneault 2005). The story is not very different for cities constituting the anchors of PURs. The emerging hypothesis is that the more they 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 other words, 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.

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 minimise 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) detect 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 (1956) classical formulation. Recent research has therefore argued that connections promoting functional integration within PURs are even more important for economic performance than long-distance connections between different PURs (Sweeney 2016), as the former work to maximise 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, that is, to share more efficiently existing resources, co-ordinate 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 minimise the fragmentation of PURs, and, again, make them resemble more large agglomerations governed by a single institutional body.

A history of co-operation between cities (institutional integration) and enhanced mobility (functional integration) is 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. 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 & 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.

RESEARCH APPROACH

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 2005), or measuring primacy (e.g. ESPON 2007). 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 'primacy' is its essence, which parallels nicely with the basic idea that polycentricity is about the lack of a primate 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 (ESPON 2007). The classification only accounts for PURs that contain at least two such agglomerations, with a minimum of 40,000 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 (>500,000) 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 per cent. 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. Table 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[2] (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 greatest number of constituent cities (39). Almost 122 million Europeans live in PURs, which corresponds to 25 per cent of

Table 1. *Polycentric urban regions in Europe.*

Country	Polycentric urban region	Polycentricity (Herfindahl–index)	No. of MUAs included	Population size[a] (x 1000)
AT	Linz–Wels–Steyr–Amstetten	0,48	4	985
AT	Klagenfurt–Villach–Wolfsberg	0,40	3	483
AT/DE/CH	Sankt Gallen–Bregenz	0,15	11	780
BE	Flemish Diamond	0,33	10	5.103
BG	Plovdiv–Pazardzhik–Asenovgrad	0,48	3	612
BG	Sliven–Yambol	0,53	2	220
BG	Haskovo–Kardzhali	0,52	2	170
BG	Shumen–Targovishte	0,53	2	170
BG	Veliko Tarnovo–Gabrovo	0,50	2	166
BG	Vraca–Montana	0,51	2	148
BG/RO	Calarasi–Silistra	0,51	2	139
CH	Zürich	0,48	10	1.615
CH	Bern–Neuchâtel–Biel–Thun	0,21	9	859
CH	Lausanne–Vevey–Yverdon–Monthey	0,54	4	439
CH	Locarno–Bellinzona	0,50	2	99
CH/FR	Genève–Annemasse–Annecy–Cluses	0,45	4	1.200
CZ	Olomouc–Zlin–Prerov–Prostejov	0,28	4	612
CZ	Decin–Teplice–Usti nad Labem	0,27	4	495
CZ	Hradec Kralove–Pardubice	0,50	2	322
DE	Rhein–Ruhr (Cologne–Dusseldorf–Essen–Dortmund)	0,12	39	12.190
DE	Rhein–Main	0,36	7	4.149
DE	Rhein–Neckar (Mannheim–Ludwigshafen–Heidelberg)	0,20	8	2.931
DE	Leipzig–Halle	0,52	3	1.214
DE	Bielefeld–Detmold	0,44	4	1.173
DE	Braunschweig–Wolfsburg	0,32	4	1.004
DE	Chemnitz–Zwickau–Aue–Greiz	0,42	4	940
DE	Erfurt–Jena–Weimar	0,23	7	853
DE	Ulm–Aalen–Heidenheim	0,34	4	683
DE	Wilhelmshaven–Emden	0,53	2	332
DE	Amberg–Weiden(Oberpfalz)	0,50	2	276
DE	Ravensburg–Kempten	0,50	2	208
DE	Stralsund–Greifswald	0,50	2	181
DE/FR	Strasbourg–Baden–Offenburg–Haguenau	0,45	6	1.048
DK	Herning–Holstebro–Skive–Ringkøbing	0,36	4	279
DK	Kolding	0,50	2	171
DK/SE	Öresund	0,49	7	2.842
EE	Narva–Kohtla Jarve	0,52	2	141
ES	Oviedo–Gijon–Aviles	0,28	5	844
ES	Alicanta–Elche	0,42	3	793
ES	Cadiz–Jerez–Sanlucar	0,42	3	668
ES	Vigo–Pontevedra–Vilagarcia	0,53	3	638
ES	Almeria–Roquetas–Ejido	0,46	3	322
ES	Jaen–Linares	0,55	2	264
ES	Algeciras	0,51	2	206
ES	Toledo–Aranjuez	0,54	2	147
ES	Ciudad Real–Puertollano	0,50	2	143
ES/FR	Donostia–San Sebastian–Bayonne	0,37	4	1.391
FR	Marseille–Aix–en–Provence	0,50	6	1.530

Table 1: *Continued*

Country	Polycentric urban region	Polycentricity (Herfindahl–index)	No. of MUAs included	Population size[a] (x 1000)
FR	Metz–Nancy–Thionville–Hagondange	0,27	5	943
FR	Dunkerque–Calais–Saint–Omer	0,44	3	486
FR	La Rochelle–Niort–Saintes–Rochefort	0,34	4	396
FR	Pau–Tarbes–Oloron–Sainte Maire	0,55	4	369
FR	Valence–Privas–Romans–Montelimar	0,42	4	313
FR	Béziers–Narbonne	0,53	2	196
FR	Cholet–La Roche sur Yon	0,50	2	172
FR/BE	Lille	0,22	15	3.115
FR/DE/CH	Basel–Mulhouse	0,32	6	982
FR/IT	Nice–Côte d'Azur–San Remo	0,27	7	1.189
GR	Larisa–Volos	0,52	2	211
GR	Alexandroupolis–Komotini	0,50	2	106
HU	Szeged–Mako–Szentes–Hodmezovasarhely	0,43	4	371
IT	Napoli	0,42	10	3.714
IT	Venezia–Padova	0,43	3	1.401
IT	Firenze	0,39	6	1.090
IT	Parma–Reggio Emilia–Sassualo	0,31	4	675
IT	Messina–Reggio del Calabria	0,35	5	670
IT	Bari	0,51	7	584
IT	Lecce–Brindisi–Gallipoli–Nardo	0,43	4	532
IT	Ancona–Fano	0,24	6	494
IT	Trento–Bolzano	0,32	4	448
IT	La Spezia–Massa–Carrara–Viareggio	0,27	4	433
IT	Foggia–San Severo–Manfredonia	0,31	4	382
IT	Salerno	0,51	3	373
IT	Latina	0,26	5	320
IT	Cosenza–Lamezia Terme	0,53	2	313
IT	Agrigento–Caltanisetta	0,23	5	269
IT	Marsala	0,53	2	127
IT	Altamura	0,52	2	105
IT/CH	Milano	0,48	16	6.011
LU/BE/DE/FR	Luxembourg	0,17	9	983
NL	Randstad (Amsterdam–Rotterdam–The Hague–Utrecht)	0,09	39	6.787
NL	Noord–Brabant (Eindhoven–Tilburg–Den Bosch–Breda)	0,11	17	2.083
NL	Groningen–Assen	0,46	3	467
NL	Middelburg–Vlissingen	0,34	3	176
NL/DE	Arnhem–Nijmegen–Apeldoorn–Wageningen	0,14	11	1.257
NL/DE	Enschede–Almelo	0,30	5	518
NL/DE/BE	Maastricht–Aachen–Heerlen–Liège	0,15	11	3.060
NO	Skien–Larvik	0,56	2	204
NO	Kristiansand–Arendal	0,54	2	188
PL	Gdansk–Gdynia	0,54	2	993
PL	Bydgoszcz–Torun	0,55	2	721
PL	Plock–Wloclawek	0,50	2	300
PL	Legnica–Jelenia Gora	0,50	2	256
PL	Lomza–Ostroleka	0,50	2	156
PL/CZ	Silesian–Moravian	0,34	24	5.294

Table 1: *Continued*

Country	Polycentric urban region	Polycentricity (Herfindahl–index)	No. of MUAs included	Population size[a] (x 1000)
PL/DE/CZ	Liberec–Gorlitz	0,29	3	346
PT	Porto–Braga–Guimaraes	0,43	10	2.391
RO	Galati–Braila	0,51	2	556
RO	Hunedoara–Deva	0,50	2	153
SE	Linköping–Norrköping	0,50	2	407
SE	Halmstad–Varberg–Falkenberg	0,53	3	200
SE	Trollhättan–Uddevalla	0,50	2	184
SK	Zilina–Martin	0,51	2	254
SK	Trencin–Povazska Bystrica–Banovce	0,38	3	216
SK/HU	Nitra–Trnava	0,19	7	550
UK	Leeds–Bradford	0,21	8	2.302
UK	Liverpool–Birkenhead	0,44	9	2.241
UK	Tyneside	0,47	7	1.599
UK	Sheffield	0,41	6	1.569
UK	Portsmouth–Southampton	0,38	6	1.547
UK	Nottingham–Derby	0,34	6	1.534
UK	Cardiff and South Wales	0,36	7	1.097
UK	Norwich–Lowestoft	0,35	5	675
UK	Ipswich–Colchester–Clacton on Sea–Felixtowe	0,37	4	538
UK	Thanet–Ashford–Canterbury–Dover	0,30	4	391
UK	Blackburn	0,52	2	391
UK	Kettering–Corby	0,50	2	140

Note: [a]Calculation based on ESPON (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.

the population of the EU (+Norway and Switzerland).

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 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 other control variables need to be considered as well, such as tourism, GDP per capita and country dummies (Meijers & Burger 2017), network connectivity (Meijers *et al.* 2016) and capital city status (Cardoso &

Table 2. *Zero–inflated beta regression on metropolitan functions in single European cities (MUAs).*

Model 1	Coefficients
Proportion part	
Population size city (MUA)	0.00086 (0.00014)**
Population size hinterland (region–MUA)	0.00017 (0.00007)*
Capital city (dummy)	0.42061 (0.24008)
GDP per capita	0.02477 (0.00481)**
International political network embeddedness	1.05283 (0.57242)
Network connectivity (airport)	−1.50303 (0.43837)**
Tourism	1.74959 (0.25878)**
Country dummies	YES
Zero–inflated part	
Population size city (MUA)	−0.02389 (0.00291)**
Population size hinterland (region–MUA)	.00021 (0.00017)
Capital city (dummy)	−6.53248 (6.61642)
GDP per capita	−0.02901 (0.01063)**
International political network embeddedness	−12.24583 (63.18845)
Network connectivity (airport)	.104825 (0.83187)
Tourism	−4.49373 (0.88874)**
Country dummies	YES
Number of observations	1,947
ln phi	4.00166 (0.10442)**

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

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 2 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.

The primary relevance of the beta regression equation presented in Table 2 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 it 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 ($p < 0.05$) less metropolitan functions than we would expect; PURs that 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

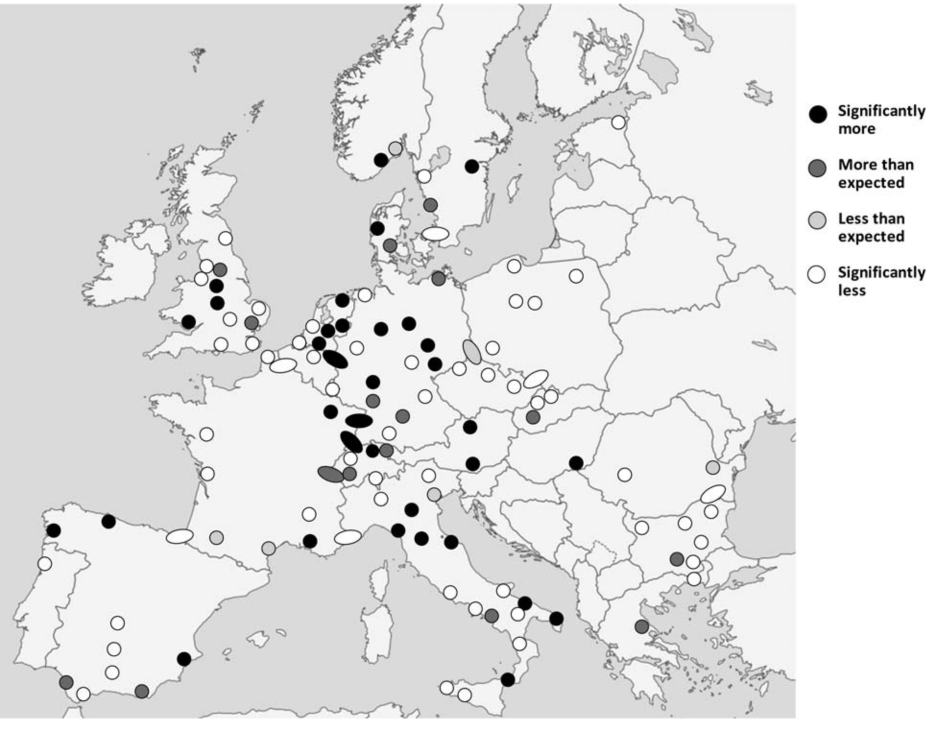

Figure 1. *Performance levels of PURs across Europe.*

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.

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 3). These three dimensions are derived from the 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. Our indicators for integration could only be collected for a year in the 2014–2016 interval, which is several years later than the data used to determine the dependent. This is not the ideal situation, but most indicators do seem fairly constant through time.

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.

Table 3. *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 co–operation covering more than 50 per cent 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 co–operation 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 per cent of the PUR population speaks a different language.	Higher = more integrated	Based on 'Languages of Europe' map

Table 4. *Descriptive statistics.*

	Mean	Standard deviation	Minimum	Maximum
Efficient road connections	1.12	0.20	0.30	1.59
Efficient rail connections	0.65	0.41	0	2.63
Frequency train connections	23.56	20.63	0	98
Presence of a metropolitan body	0.48	0.50	0	1
Number of years active	4.74	7.79	0	41
Type of partnership	1.18	1.36	0	4
Political preference homogeneity	0.60	0.21	0.31	1
Language homogeneity	0.86	0.35	0	1

Institutional integration is measured by indicators reflecting the level of co-operation of local governments. This is assessed on a case-by-case basis 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 scope and autonomy, from informal, sectoral agreements to wide-ranging, formalised authorities. To be considered, such entities had to cover at least 50 per cent of the population of a PUR.

The measurements of cultural integration focus on whether cities in a PUR are culturally proximate, as reflected by the political colour of their mayor. The underlying assumption is that the cultural-political signature of a city is reflected in the political colour of a mayor, which probably holds more in the majority of European countries where the mayor is directly elected by the local population, or indirectly by the municipal council, than in the few countries where they are appointed by central government. Feasibility constraints did not allow us to explore how well our 'snapshot' of the current situation provides a robust picture over a longer time period, but we believe that it is fair to say that a city run by a labour mayor tends to be culturally somewhat different from a city run by a Christian-democrat or liberal mayor. Previous studies (Hoffmann-Martinot & Sellers 2005) have stressed the barriers caused by gaps of political orientations (e.g. left-leaning core cities vs. conservative suburbs), which force governments to respond to very different electorates. More compatible political preferences between cities indicate less contrasting sets of aspirations, and greater cultural integration. Another cultural barrier is language. We assume that if language barriers divide PURs, in the sense that the dominant language in one or more of its constituent cities differs from what the majority of people speaks in another city of the same PUR, this will negatively affect their performance. This often occurs in cross-border PURs, but for instance also in the central Belgian urban network known as 'Flemish Diamond'.[3]

The individual indicators in Table 3 have also been aggregated, after normalising, 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 4, and correlation matrices in Table 5 and Table 6 (indices) respectively. We reflect on the multicollinearity between 'presence of a metropolitan body' and 'type of partnership' below.

RESULTS

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 7 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 (models 2–4), and then the effect of their combination (models 5 and 6).

Table 5. *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	0.10	1.00					
(4) Presence of a metropolitan body	0.08	−0.04	0.44**	1.00				
(5) Number of years active	0.19*	0.04	0.34**	0.64**	1.00			
(6) Type of partnership	0.008	−0.03	0.47**	0.91**	0.58**	1.00		
(7) Political preference homogeneity	0.00	0.11	0.09	0.03	−0.02	0.12	1.00	
(8) Language homogeneity	0.02	0.11	−0.04	−0.12	−0.13	−0.06	0.14	1.00

Note: $^{**}p < 0.01$, $^{*}p < 0.05$.

Table 6. *Correlation matrix indices.*

	(1)	(2)	(3)
Functional integration index	1.00		
Institutional integration index	0.10	1.00	
Cultural integration index	0.30**	−0.04	1.00

Note: $^{**}p < 0.01$, $^{*}p < 0.05$.

Table 7 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 per cent 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 models 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 us mainly to compare between the models presented here.

Table 8 presents the results for the institutional integration variables, again showing

Table 7. *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 (0.901)			0.609 (0.957)	
Efficient rail connections		0.840 (0.440)#		0.687 (0.449)	
Frequency train connections			0.028 (0.009)**	0.027 (0.009)**	
Functional integration index					0.931 (0.293)**
Number of observations	117	117	117	117	117
LR chi^2	1.83	3.87*	10.13**	13.46**	11.01**
Pseudo R^2	0.007	0.0147	0.0386	0.0512	0.0419

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

Table 8. *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	0.816 (0.358)*			1.322 (0.872)	
Number of years active		0.039 (0.022)#		0.010 (0.029)	
Type of partnership			0.222 (0.130)#	−0.249 (0.303)	
Institutional integration index					0.423 (0.198)*
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

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

results for individual indicators (models 7–9) and their combined effect (models 10 and 11).

Although 'presence of a metropolitan body' and 'type of partnership' were clearly correlated (see Table 5), 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 co-operation is associated with better performance, but this is only significant at the $p < 0.10$ level. Taken together, more institutional integration between cities in PURs has a positive effect on its performance (model 11).

A possible bias here could arise from the fact that in PURs that are part of the same administrative-territorial unit (e.g. a province), the need for co-operation is less strong as this overarching administrative region takes care of the integrated development of the PUR already. This has for instance been documented for the Linköping-Norrköping PUR (Meijers *et al.* 2014). Therefore, we calculated the administrative-territorial fragmentation of PURs, by calculating the Herfindahl index based on the population shares in different NUTS 2 regions, and did the same for NUTS 3 regions, which were then subtracted from 1 so that higher values represent more fragmentation. As Figure 2 shows, there is indeed such a relation, with more fragmentation being associated with more co-operation. We also ran models (not reported) explaining the performance of PURs by their extent of administrative-territorial fragmentation, but these fragmentation indicators remained far from significant.

As for cultural integration (Table 9), 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.

Aggregate dimensions of integration – Table 10 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 the literature suggests contrasting urban dynamics (e.g. Dijkstra *et al.* 2013). In addition, we add a

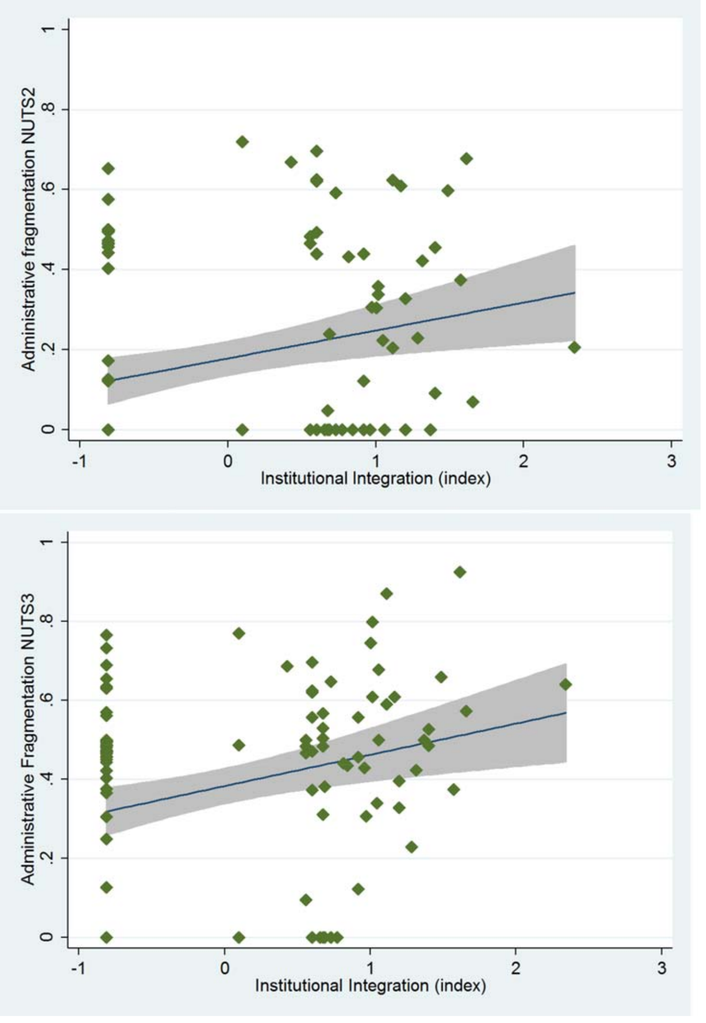

Figure 2. *The association between institutional integration and administrative fragmentation at NUTS 2-level (top) and NUTS 3-level (bottom). [Colour figure can be viewed at wileyonlinelibrary.com]*

variable indicating whether a PUR is cross-border. Many contributions have stressed the challenging conditions of the various dimensions of integration in cross-border metropolitan regions (e.g. Nelles & Durand 2014; Sohn & Reitel 2016). As for some PURs, only a small part of their territory is cross-border, we developed an indicator that reflects the degree of ‘cross-border-ness’, calculated as (1–) the Herfindahl index based on shares of PUR population in the different countries. Table 10 also explores whether there are positive feedbacks between the various forms of integration by adding interaction terms (models 18–20). Do we find evidence that, for example, stronger functional integration results in more cultural or institutional integration?

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 10. Counter to model 11, the institutional

Table 9. *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 (0.813)		1.226 (0.824)	
Language homogeneity		.439 (0.540)	.310 (0.550)	
Cultural integration index				.379 (0.239)
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

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

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 × institutional and institutional × 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.

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

Table 10. *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)	0.782 (0.304)**	0.771 (0.336)*	0.776 (0.338)*	0.769 (0.336)*	0.785 (0.339)*
Institutional integration (index)	0.302 (0.211)	0.339 (0.237)	0.363 (0.242)	0.334 (0.239)	0.348 (0.238)
Cultural integration (index)	0.349 (0.250)	0.530 (0.316)#	0.546 (0.319)#	0.525 (0.320)	0.523 (0.318)
PUR size		−0.00036 (0.00021)#	−0.00034 (0.00021)	−0.00035 (0.00021)#	−0.00036 (0.00021)#
Eastern Europe dummy		−1.151 (0.636)#	−1.097 (0.646)#	−1.156 (0.637)*	−1.146 (0.636)*
Cross–border (degree)		2.302 (1.485)	2.261 (1.488)	2.251 (1.546)	2.141 (1.536)
Interaction Functional × Institutional Integration			−0.195 (0.352)		
Interaction Functional × Cultural Integration				0.051 (0.430)	
Interaction Institutional × Cultural integration					−0.124 (0.301)
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	0.102	0.103	0.102	0.095

Notes: 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).

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 urbanisation 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 co-operation, but its exact shape and scope seem of secondary importance. There is some indication that the duration of co-operation 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; and
- 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 sociospatial 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 inputs 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 explain in greater detail the inner workings of PURs and their sometimes surprising contrasts. This should first of all include the use of other indicators to measure the three dimensions of integration, perhaps better adapted to particular contexts. While we believe that our indicators capture important aspects of integration, we also recognise that they do not, and perhaps cannot, cover the three dimensions at full length and in their entire depth. We would welcome others to explore other indicators to check the robustness of our analyses, for which we make our dataset available. Promising lines of inquiry could be, for instance, the relevance for performance of a particular division of labour between cities; the functional polycentricity of the region; finer distinctions among metropolitan governance entities, capturing national regulatory specificities and historical legacies; a more comprehensive set of cultural integration indicators reflecting for instance differences in ethnicity and religion, or perceptions of identity-building at PUR scale; and using other proxies for performance. Finally, the addition of a time dimension to understand the evolution of different forms of integration in relation to performance also needs to be part of a future research agenda.

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Notes

1. The ESPON 1.4.3 project also presents a list of what they call 'polycentric metropolitan areas (poly-FUAs)', but these are actually multicentric areas – the size distribution of the cities within these poly-FUAs is not considered, and the list includes obviously monocentric regions like Lyon metropolitan area, where the second city is almost 20 times smaller than the core city.
2. 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).
3. Other cases include Haskovo-Kardzhali (BG) and Trento-Bolzano (IT).

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