The productivity effects of polycentricity: A systematic analysis of urban regions in Europe

Abstract: We focus on the extent to which polycentric urban regions can substitute for the agglomeration economies provided by large cities. Building on an open-source software tool that helps identifying polycentric developments in urban regions, we analyze the spatial structure (in terms of size, dispersion and polycentricity) of 94 regions across 34 European countries and link this to their level of total factor productivity. We find that both more polycentric regions and more dispersed regions are associated with lower productivity levels.

Key words: polycentricity, spatial structure, agglomeration economies, productivity, Europe

JEL classification: C36, O47, R11, R12, R14, R58

1. Introduction

Cities are increasingly embedded into reconfigured urbanized regions, and thereby experience "processes of large-scale restructuring and integration of economic activities, spatial forms, and institutional arrangements" (Cardoso and Meijers 2021, p. 1). This worldwide formation of integrated urban regions has become a key area of research in urban and regional studies, as illustrated by the emerging popularity of the literature on 'city-regions' (Scott 2019), 'regional urbanization' (Soja 2015), 'polycentric urban regions' (ESPON 2004), 'extended urbanization' (Monte-Mór and Castriota 2018) and 'metropolization' (Cardoso and Meijers 2021).

In the European context, the research agenda centered on polycentric urban regions (PURs) is particularly well-developed. The PUR concept is used for studying regions that are characterized by synergies between proximate and densely connected urban centres. This spatial vocabulary is increasingly invoked to examine and explain a range of emerging European regional geographies (Harrison et al. 2019; 2022). While PUR research is part of a broader research agenda dealing with the resurgence of regions in terms of institution-building, identity formation, and emerging spaces of democracy and citizenship, much of the literature has focused on issues of economic development and competitiveness. A key question in this debate centers on describing and explaining the nature of the relationship between regional spatial structure and economic productivity (Ouwehand et al. 2022).

Despite the relative abundance of spatial-econometric analyses in PUR research, the evidential base remains fragmented and uneven (Rauhut 2017). This is especially striking in this European context, where polycentric development has become a paradigm in regional development policies on a variety of territorial scales (Meijers and Sandberg 2008, ESPON 2020). Given this, the PUR framework not only serves academic purposes but has increasingly "garnered considerable attention for framing territorial politics and governance" around the normative and combined goals of achieving territorial cohesion and economic competitiveness (Harrison et al. 2022, p. 1).

Nonetheless, empirical evidence for such claims remains scarce and often contradictory (Davoudi 2007, Wegener 2013), and “urgent questions remain about the veracity of polycentric development as a spatial policy tool” (Harrison et al. 2022, p. 3). Against this background, in this paper we build on recent claims (Brezzi and Veneri 2015, Wang et al. 2019, Ouwehand et al. 2022) that it is important to further develop our understanding of the relationship between regional spatial structure – focusing on polycentric patterns – and regional economic performance. In so doing, this paper seeks to contribute to an emerging body of research that systematically investigates the alleged economic advantages of urban-regional integration at the pan-European scale (ESPON 2005, 2007 and 2012, Vandermotten et al. 2007, Brezzi and Veneri 2015, Meijers et al. 2018, Ouwehand et al. 2022).

More specifically, we contribute to this debate by extending recent efforts to analyze polycentric development (from a morphological perspective), economic productivity, and their relationship in more innovative ways (see also Section 2.4). First, our analysis builds on more robust, comparative, and reproducible assessments of the spatial conditions shaping PURs in a European context. Second, by invoking the method developed by Ouwehand et al. (2022), we measure economic productivity in terms of total factor productivity (TFP). Our contribution nonetheless extends their work as we: (i) collect data on a more fine-grained territorial level and link this in an innovative way to the geographical units constituting our set of PURs, (ii) derive empirical findings for a larger European territory including more than twice as many countries, and (iii) verify to extent to which there are spatially dependent relations between the variables .

We find no empirical evidence for the often-hypothesized positive impact of urban polycentricity on regional economic productivity in Europe. We instead observe either a negative or no effect, depending on the inclusion of variables reflecting regional population size and spatial dispersion. Our observations thus hint at the continuing importance of single-centre agglomeration benefits.

The remainder of this paper is organized as follows. We begin by reviewing the key debates relevant to our paper. This is followed by a discussion of our research design and subsequently an overview of our empirical results. We conclude the paper with an overview of our findings and their implications for a future research agenda.

2. Literature review

2.1 Policy narratives and theoretical foundations

The importance of polycentric development in Europe is emphasized in all key EU strategic documents dealing with territorial development: the European Spatial Development Perspective (ESDP 1999), the EU Territorial Agenda 2030 (TA 2030) and the 'Pact of Amsterdam' which established an EU Urban Agenda (2016). Many European countries also pursue polycentric development policies at the (sub-)national level (Waterhout et al. 2005).

This policy emphasis is fueled by the hypothesis that polycentric urban systems have the potential to reconcile the combined goals of more territorial cohesion *and* more territorial competitiveness (Gløersen 2007). Theoretical substantiation for these policy narratives is largely drawn from scientific debates in the fields of regional science and economic geography dealing with the relationship between agglomerations and economic productivity. Here, the observation that economic productivity has historically been higher in larger cities is attributed to 'agglomeration externalities' (see Andersson and Lööf 2011 for an overview): economic actors may benefit from their presence in agglomerations as these offer a diversified and large labor pool, large local markets and strong service provisioning (urbanization externalities), as well as advantages that arise from the co-presence of actors in the same (localisation externalities) or another (complexity externalities) economic sector (van Meeteren et al., 2016c).

However, several studies (e.g. Meijers and Burger 2010 and Dijkstra et al. 2013) suggest that the advantages of agglomerations can be ‘regionalized’ and that PURs may reach similar (or even higher) levels of productivity compared to more monocentric regions with similar populations. This hypothesis was first put forward by Alonso (1973, p. 200) through the idea that “small metropoles in megapolitan complexes, such as that on the Atlantic seaboard, have much higher incomes than independent metropoles of equivalent size” because these would have access to agglomeration benefits of larger neighboring cities. By referring to the concept of ‘borrowed size’ Alonso argued that, while retaining many of the advantages of smaller-sized cities, these metropoles “enjoy the advantages of larger size through their easy access to other centers” (Ibid.). Recent EU policy papers specifically refer to these borrowed size dynamics. For example, ESPON (2020, p. 2) states that polycentric development “is about building linkages and joining forces with neighbouring cities and towns in order to “borrow” size and quality, to create a stronger critical mass and ensure positive spill-over effects for the development of wider regions”.

However, for all this policy emphasis on polycentric development and its supposed advantageous impact on economic productivity, the evidential base remains fragmented. The increasing number of empirical studies investigating this link in different countries worldwide (China in particular) and at different geographical scales (within ‘cities’ and within ‘(mega)regions’) has led to an increasingly heterogenous collection of outcomes. Some of these studies find evidence that polycentricity is associated with higher economic productivity (e.g., Meijers and Burger 2010 and Meijers 2013 for the case of US metropolitan areas and Veneri and Burgalassi 2012 for Italian NUTS 2 regions), whereas others find negative (e.g., Li et al. 2019 for Chinese prefecture-scale regions and Veneri and Burgalassi 2011 for Italian

NUTS 3 regions) or no significant relations (e.g., Lee and Gordon 2007 for the case of US metropolitan areas).

What is largely absent from this literature are studies that systematically investigate this relationship at the scale of the European territory. Additionally, the literature has predominantly focused on the ‘intra-urban’ (Davoudi 2003) scale (the organization of cities at the local level), as opposed to analyses at the ‘inter-urban’ (or regional) scale (van Meeteren et al. 2016a). From the perspective of the European Union-wide policy agenda on urban development and regional productivity, the latter scale is arguably very important (Meijers 2008a). In the next section, we therefore zoom in on the few studies that have linked regional polycentricity and economic productivity in a systematic way at the European scale, and we interpret, compare and discuss their findings.

2.2 Diverging findings at the pan-European level

Table 1 provides an overview of empirical studies that have systematically investigated the link between polycentric urban regions and regional economic productivity at the European scale[1]. We list their geographic scope, the key characteristics of their analytical-operational scheme, and a summary of their main findings.

It is clear from this exercise that findings diverge significantly. While ESPON (2004) finds a positive association, ESPON (2007) does not, and argues that more monocentric countries perform slightly better. The latter conclusion is shared by Vandermotten et al. (2007) and Meijers and Sandberg (2008). Brezzi and Veneri (2015), in turn, find diverging outcomes at different scales: a positive association at the national level and a negative one at the regional level. Contrary to the latter finding, Meijers and Burger (2017) conclude that borrowed size processes appear to occur more frequently in more polycentric metropolitan areas. The most

[1] While the work of Meijers et al. (2018) (investigating functional, institutional, and cultural integration across PURs in Europe) closely aligns with this research purpose, it does not explicitly analyze the relationship between *degrees of* urban polycentricity and economic productivity.

recent study by Ouwehand et al. (2022) finds no direct impact of polycentricity on productivity and argues that the impact is more markedly negative when urban size increases.

Part of the reason for this fragmented evidential base is the lack of a common and shared understanding of what polycentricity is and how it should be measured. For example, in the case of the two conflicting ESPON report findings, Meijers (2008a) illustrated that both studies build on different conceptualizations (purely morphological versus the inclusion of 'functional aspects'[2]) and measurements (a rank-size distribution versus a primacy or a standard deviation-based approach) of polycentricity. In fact, this observation applies to all studies in Table 1 and is evident from the variety in analytical-operational schemes; while all studies devised morphological indicators (which measure a degree of 'balance' between morphologically defined urban centers), the type of sub-indicators used, their composition into an aggregate index, units and scales of analysis all vary. As Derudder et al. (2021) have demonstrated empirically, even slight differences in how these elements are defined and operationalized may result in very different empirical outcomes.

A similar explanation holds for the way in which economic productivity is measured. Next to differences in geographical scales (ranging from the national to a range of regional levels), Table 1 includes different analytical schemes. The majority employs (growth in) gross domestic product (GDP) per capita, under the assumption that it proxies a region's overall productivity. An evident reason for the abundance of this measure in pan-European studies is its data availability across (sub)national scales. More recently, however, Ouwehand et al. (2022, p. 57) introduced total factor productivity (TFP) as an allegedly "better" measure for analyzing differences in regional economic development in a European context (see also section 2.4). In any case, earlier work in this European context (Spiezia 2003, Brezzi and Veneri

[2] Note that these 'functional aspects' should not be interpreted as reflecting actual *relationships* between urban centres. Rather, they pertain to indicators that measure the intensity of particular (administrative, cultural, tourism etc.) functions.

2015) demonstrated that economic productivity measures are very sensitive to the level of territorial disaggregation at which data are gathered. Additionally, different measures may lead to different outcomes (Meijers and Sandberg 2008).

Over and above the observation that different analytical-operational schemes may contribute to different findings, several other arguments are invoked by the different studies listed in Table 1 to help make sense of these diverging outcomes. In the next section, we turn to those empirical findings in Table 1 that seem particularly counter-intuitive when reasoning from the optimistic EU policy narrative discussed in the previous section.

Source	Geographic scope	Analytical-operational scheme					Main findings	
		Unit of analysis	*Scale of analysis*	*Measurement of polycentricity*	*Measurement of economic performance*	*Measurement of relationship*		
ESPON (2004)	29 countries	Functional urban areas	National	Polycentricity index (morphological, 7 sub-indicators)	GDP/capita (measured at the national level)	Correlation analysis	More polycentric countries tend to be associated with a higher GDP/capita. These correlations are stronger for the old EU-15 than for the recently accessed countries.	+
ESPON (2007)	29 countries	Functional urban areas	National 'Macro-regions'	Polycentricity index (morphological, 5 sub-indicators)	GDP/capita: growth over time (measured at the national and NUTS 3 level)	Correlation analysis	No significant correlation was found, but from the direction of the correlation it appears that the more monocentric countries score slightly better.	°
Vandermotten et al. (2007)	25 countries	Functional urban areas	National 'Macro-regions'	Polycentricity index (morphological, 4 sub-indicators)	GDP/capita: growth over time (measured at the national and NUTS 3 level)	Correlation analysis	More monocentric regions are more successful, both at the scale of the state and of the macro-regions.	-
Meijers and Sandberg (2008)	20 countries	Functional urban areas	National	Polycentricity index (morphological, 2 sub-indicators)	GDP/capita and unemployment rate: growth over time (measured at the NUTS 2 level)	Correlation and regression analysis	The more polycentric a country's urban system is, the more there exist regional disparities in terms of GDP per capita within that country.	-
Brezzi and Veneri (2015)	29 countries	Functional urban areas	National Regional	Primacy and rank-size distribution (morphological)	GDP/capita (measured at the OECD TL2 level)	Regression analysis	Relatively more monocentric regions have higher GDP per capita than their more polycentric counterparts (regional level). At the country level, however, polycentricity is associated with higher GDP per capita	+/-
Meijers and Burger (2017)	27 countries	Functional urban areas	Regional	Herfindahl-Hirschman Index (morphological)	Presence of metropolitan functions (measured at the LAU2 level)	Correlation analysis and regression analysis	Borrowed size processes appear to occur more frequently in polycentric as compared to monocentric metropolitan areas.	+
Ouwehand et al. (2022)	16 countries	OECD TL2 regions	Regional	Rank-size distribution (morphological)	Total factor productivity (TFP) (measured at the OECD TL2 level)	Regression analysis and instrument variables analysis	Polycentric urban structures have no directly identified impacts on productivity and polycentricity negatively impacts regional productivity as size increases.	°
This paper	34 countries	Urban centres (GHSL definition)	Regional	Polycentricity index (morphological, 4 sub-indicators)	Total factor productivity (TFP) (measured at the NUTS 3 level)	(Spatial) regression analysis and instrument variables analysis	More polycentric regions are associated with lower levels of productivity, especially when the population in those regions is also more dispersed.	-

Table 1: Studies linking polycentricity and economic performance at the pan-European level

(the '+', '-' and '°' signs indicate statistical significance: positive, negative or not significant)

2.3 Making sense of non-significant and negative associations

Studies that arrive at negative or non-significant relations between the degree of regional polycentricity and productivity levels imply that agglomeration economies did not regionalize to the extent anticipated in policy circles. Several explanations have been put forward.

ESPON (2007) largely avoids discussing plausible explanations for the non-significant correlations found, but the authors do indicate that interpretations should be situated “in the framework of a globalization and tertiarization of the economy benefiting big cities, which are the strongest integration nodes in the world economy” (Ibid., p. 232). Vandermotten et al. (2007, p. 56) agree by stating that the negative link “seems consistent with the main present trends towards more globalization, which favor the main advanced service nodes of the world-wide economy”. From this perspective, economic competitiveness is (most) strongly interwoven with the position of cities and regions in systems of global production networks (Lambooy 1993, McCann and Acs 2011) and less so with a regionalization of local agglomeration benefits.

Brezzi and Veneri (2015, p. 15) argue that the negative link at the regional scale suggests “that physical distance and agglomeration of people and workers have an important role for socio-economic conditions in regions”. In other words, regionalized agglomeration economies do not replace single-centre agglomeration effects, because “physical proximity is still more important than relational proximity at the regional scale” (Veneri and Burgalassi 2011, p. 4). As pointed out in Meijers and Burger (2017), these outcomes correspond to earlier empirical work in the Netherlands in which PURs were linked to lower performance due to a (hypothesized) need for longer travel and commodity flows, less convenient information flows, and a duplication of lower-order urban functions in subcenters due to inter-urban competition and rivalry (see also Parr 2004, p. 236). Besides the continuing importance of physical proximity (however, see Hesse 2014), Parr (2004) mentions the related advantages that urban density may bring in terms of face-to-face or unplanned interaction, and suggests that PURs may be loci of 'economic stress' due to small-scale infrastructure facilities, dispersed urban populations, the lack of high-order business services and competition between centers.

Some of these elements are also raised by Partridge et al. (2009) for the United States and Meijers and Burger (2017) for Europe, by suggesting that a negative link between PURs and economic performance may be attributed to 'growth shadow effects' or 'agglomeration shadows'. This concept, which emerged in New Economic Geography (NEG) (Krugman 1991) circles, describes a situation in which growth near concentrations of firms may be limited due to competition effects (for instance, concentration of productive activities in one region may drive up land rents and housing prices). As suggested by Meijers and Burger (2017, p. 274), this shadow effect of firm agglomeration on surrounding areas can manifest itself in a PUR context, because "neighbouring cities may cast an agglomeration shadow, consequently limiting development opportunities". In other words, the existence of agglomeration shadows may prevent urban areas from developing too closely to other (equal or larger-size) urban areas.

Ouwehand et al. (2022) do not elaborate on their finding that polycentricity does not have a significant positive effect on productivity in European regions, other than stating that "the urbanization externalities derived from multiple city cores do not substitute for those achieved with a structure relying on singular, larger cities" (p. 58). In line with Meijers and Burger (2010) and Veneri and Burgalassi (2011) they do however include additional variables capturing different aspects of regional spatial structure that may help qualify their observations: (i) urban size and (ii) a degree of dispersion. It may indeed make sense to incorporate these characteristics (and examine their interaction effects with polycentricity) since the (potential) effect of a polycentric urban-regional structure obviously does not operate in isolation of other (potential) spatial effects. In fact, in a European context, (i) the *size* of the constituent cities in a PUR has been associated with higher regional productivity (Veneri and Burgalassi 2011, Meijers and Burger 2017, Ouwehand et al. 2022), and (ii) the extent to which a region's population is *dispersed* across its territory may impact economic productivity (Veneri and Burgalassi 2011 found a negative relationship while Ouwehand et al.'s work did not yield any significant results). When modelling the *combined* effects of size and polycentricity, Meijers and Burger (2010) and Ouwehand et al. (2022) both find that polycentricity negatively impacts regional productivity as size (measured in terms of aggregated regional population) increases. In other words: "polycentricity does not work for urban regions with a relatively larger population in particular" (Ouwehand et al. 2022, p. 58). While this seems to align with Alonso's (1973) original reflections on borrowed size (in which especially *smaller* cities in multicentric metropolitan areas would reap the benefits of agglomeration), Veneri and Burgalassi (2011) find no such evidence and Meijers and Burger (2017, p. 284) arrive at a positive interaction effect of size and polycentricity, as "borrowed size effects occur more often in larger cities, and especially among those that form part of a polycentric metropolitan entity".

2.4 Proposed approach

In the previous sections we took stock of a number of important developments in the literatures on territorial governance and the economic productivity/spatial structure nexus, focusing specifically on the European context. In this paper, we build on these and at the same time incorporate a number of original contributions which are outlined in the next paragraphs.

Section 2.2 elaborated on the thorny issue of different analytical-operational frameworks possibly leading to different outcomes. In terms of the measurement of urban polycentricity, this paper addresses this issue by building on recent contributions in the PUR literature (Derudder et al. 2021 and Caset et al. 2022) that have culminated in the development of an open-source software tool called PURban. This tool brings together the major analytical-operational frameworks and datasets in urban polycentricity research and identifies, maps, and analyzes degrees of morphological polycentricity in European urban systems. It integrates several different measures (such as rank-size rule or standard deviation-based approaches) and it allows to tailor several analytical specifications (such as a maximum spacing between urban centres or a minimum population potential). Additionally, our analysis is not confined to administrative urban and regional/national delineations. Thus, unlike a "modular approach" (Ouwehand et al. 2022, p. 54) which is employed "for the sake of simplicity" (Brezzi and Veneri 2015, p. 9) in which cities cannot transcend regional borders, our approach is not dictated by administrative territorialities but by the morphological realities on the ground. We believe *our analysis builds on more robust, comparative and reproducible assessments of the spatial conditions shaping PURs in a European context.*

In terms of measuring economic productivity, we draw on recent work arguing that, in a European context, it may be particularly relevant to analyze differences in regional economic development in light of a measure that captures technological sophistication and production efficiency: total factor productivity (TFP). This was recently suggested by Beugelsdijk et al. (2017, p. 462), who clarified that "contemporary EU Cohesion Policy emphasizes the role of technological progress, innovation and knowledge externalities (…), recognizing that improvements in productivity are key to enhancing regional economic performance, and that innovation and knowledge creation are critical to achieve such productivity gains." Their work subsequently demonstrated that differences in economic development across subnational regions in Europe can largely be attributed to differences in TFP. *Here, we invoke an analytical-operational scheme to measure economic productivity in terms of TFP* initially developed by Ouwehand et al. (2022).

While Ouwehand et al. (2022) also calculated TFP and linked this to spatial structure in European regions, our work differs in several respects. First, as mentioned in Section 2.2, economic productivity measures are highly sensitive to the level of territorial disaggregation at which data are gathered. Compared to Ouwehand et al., we collect data on a more fine-grained territorial level (NUTS3 instead of OECD TL2 level) and link this in an innovative way to the geographical units of the urban centres in urban regions (URs) (see Section 3.3 and the Appendix for more detail). Briefly summarized, *we work with more recent data at a more fine-grained territorial level* (the level of urban centres and of NUTS-3 regions) and devise a methodology that links both scales and is able to deal with situations in which urban centres cross administrative borders. Second, compared to Ouwehand et al. (and the other sources in Table 1), *we derive empirical findings for a larger European territory*, including more than twice as many countries as Ouwehand et al. (2022). And thirdly,, drawing on spatial econometric techniques, we verify the extent to which there are spatial dependencies between the variables in the models.

3. Data and methods

Our analysis comprises 34 European countries, focuses on inter-urban polycentricity at the regional scale, adopts a morphological perspective by drawing on the 'degree of urbanization' framework (Dijkstra and Poelman 2014), measures economic productivity in terms of TFP, includes additional spatial structure variables (size and dispersion), and assesses the link between spatial structure and economic productivity by means of regression and instrument variables analysis. These key operational aspects are briefly spelled out below.

3.1 Center definition, polycentricity measurement and field of study

PURban, presented in Caset et al. (2022), defines the building blocks (or 'cities') of PURs on the basis of the Global Human Settlement Layer (GHSL) Urban Centre Database (hereafter GHS-UCDB, see Florczyk et al. 2019a). This database is based on the 'degree of urbanization' concept (Dijkstra and Poelman 2014), which devises a consistent definition of urban areas to create a global database of 'urban centres' (UCs). By this token, each UC is a high-density cluster of contiguous grid cells of 1 km^2 with a population density of at least 1.500 inhabitants per km^2 or a built-up area of at least 50%, and a minimum total population of 50.000. In total, the 34 countries of our analysis contain 734 UCs[3] (see Figure 1A for a geographical representation of all (centroids) urban centres in the analysis).

To systematically calculate degrees of polycentricity across the European territory, PURban takes an algorithmic approach built around the key spatial conditions for morphological polycentricity as outlined by Parr (2004), i.e.: a sizable regional cluster of individual centres that are in close proximity to each other, without pronounced differentiation between these centers in terms of size or importance. We translated these conditions into four parameters listed below:

1. **Geographical scale**: *a maximum travel time between any pair of UCs of 45 minutes (by road, traffic congestion delays included)*[4]. This maximum limit stems from the need for sustained, face to face interaction for borrowed size to occur (Meijers and Burger 2017), and the 45 minutes corresponds to an acceptable European travel to work distance (ESPON 2004, Meijers et al. 2018). The focus on commuting is sensible since (specialized) labour market integration is a significant driver of borrowed size effects (Phelps 1998).
2. **Minimum number of urban centres**: *a minimum of two urban centres in a PUR*, in line with Meijers et al. (2018), Brezzi and Veneri (2015) and others.
3. **Critical mass**: *PURs at least have 1.5 million inhabitants*. This threshold is derived from the work of McCann and Acs (2011), who demonstrated that an urban agglomeration of 1.5 to 2 million people is a necessary condition for agglomeration externalities to develop.
4. **Balance in importance**: this parameter consolidates the four most common indicators from the European PUR literature: a primacy index (Burger et al. 2011), a Herfindahl index (Meijers et al. 2018), a rank-size slope measure (Burger and Meijers 2012) and a standard-

[3] We selected all UCs located in EU countries, except for those located on islands (i.e. in Iceland, Corse, Sardinia, Ibiza, Mallorca and Kriti). In addition, non-EU UCs that are geographically situated in-between other EU states (i.e., Kaliningrad belonging to Russia and the UCs located in Switzerland, Serbia, Albania, and other non-EU Balkan countries) are included.

[4] As we only take into consideration car travel, this creates a bias in all areas where a significant proportion of the population commutes by train.

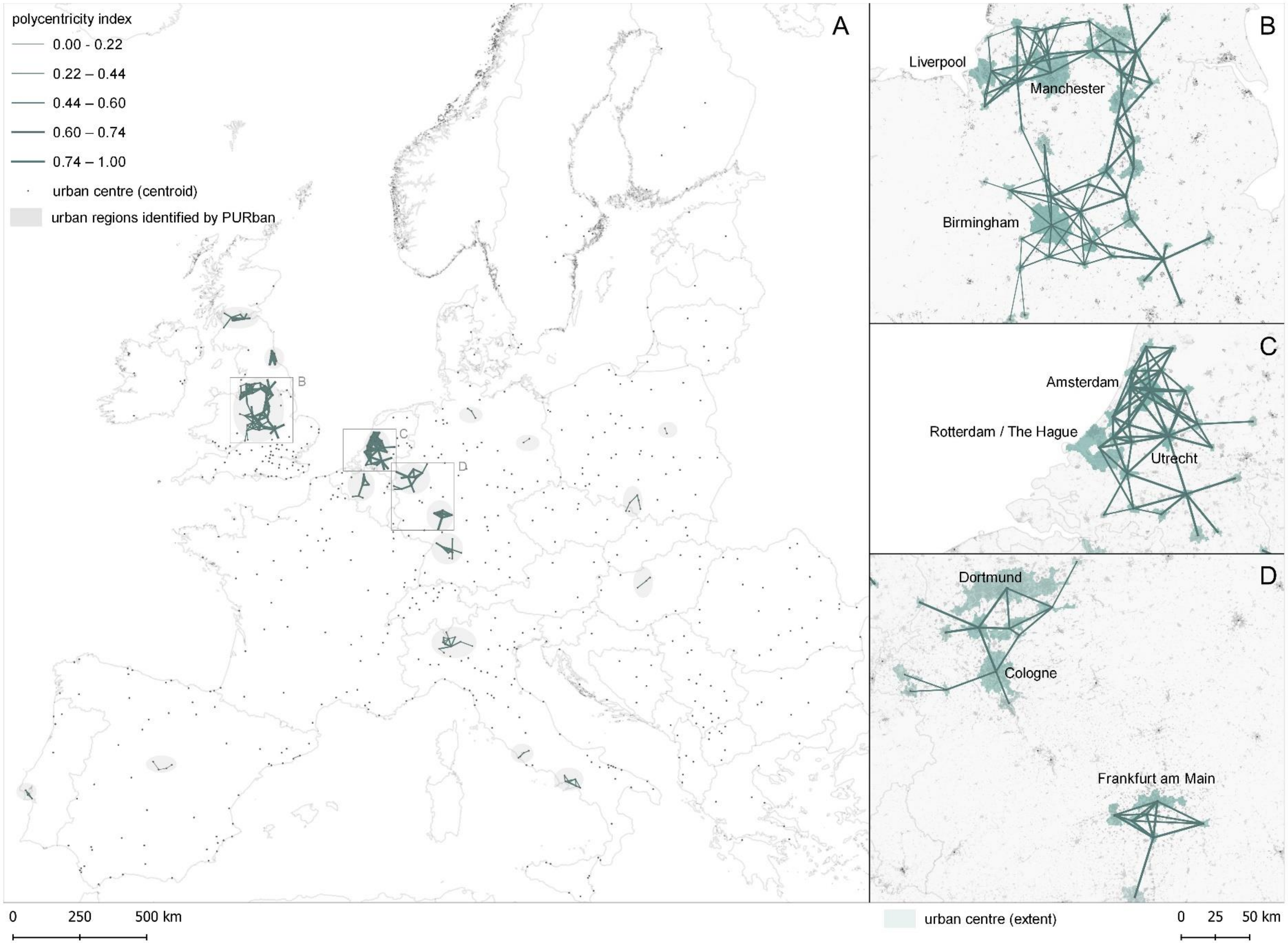
deviation based index (Green 2007). *Combining all indicators, we calculate a composite polycentricity index*[5] *that reflects the degree of morphological polycentricity for all PURs that met criteria one to three*. The higher the index value the higher the degree of polycentricity. Following Meijers and Burger (2010), we only work with the largest (in terms of total population) four urban centres of each potential PUR to calculate the polycentricity index. As empirically demonstrated by Derudder et al. (2021), this allows for a higher comparability among regions.

To summarize, in a first step, we invoke PURban to screen the area around each individual UC to verify if the conditions set by parameters 1 to 3 are satisfied. In other words, it verifies if an UC is surrounded by other UCs that are within a 45 minutes driving time, and if so, it verifies if the combined population of these UCs is at least 1.5 million. Building on this procedure, we identify a total of 94 unique urban regions (URs) located in 10 countries (see Figure 1A). This set of URs constitutes the empirical foundation for our analysis.

In a second step, we use PURban to calculate a composite polycentricity index (specified in parameter 4) for all 94 regions. These index values are visualized in Figure 1A. It is clear from this figure that some URs are much more polycentric than others, with degrees of polycentricity varying from very low (e.g. URs Warsaw, Madrid, Barcelona and Budapest) to very high (e.g. URs Amsterdam, Dusseldorf, Loughborough and Kettering). From Figure 1A, we can conclude that the overall geography of more polycentric URs largely corresponds with that in related research (e.g. ESPON 2005, Rozenblat 2009 and Meijers et al. 2018). Regions with a high density of closely spaced and balanced UCs with sufficient population are plentiful along the European 'dorsal axis', stretching from the north of England to Sicily (Rozenblat 2009). The strongest degrees of polycentricity are situated along this axis, with the Midlands

[5] The composite index was calculated using a min-max normalization for each of the four indicators. The average of these values were calculated, after which another min-max normalization was performed to arrive at a composite index with values ranging from 0 to 1.

and the Liverpool-Leeds area in the United Kingdom (Figure 1B), the Randstad in The Netherlands (Figure 1C), and the Rhine-Ruhr and Rhine-Main metropolitan areas in Germany (Figure 1D) characterized by both the highest prevalence of PURs and the highest polycentricity index values.



polycentricity index
0.00 - 0.22
0.22 – 0.44
0.44 – 0.60
0.60 – 0.74
0.74 – 1.00
urban centre (centroid)
urban regions identified by PURban
A
B
C
D
Liverpool
Manchester
Birmingham
Amsterdam
Rotterdam / The Hague
Utrecht
Dortmund
Cologne
Frankfurt am Main
0
250
500 km
urban centre (extent)
0
25
50 km

Figure 1: Empirical scope and degrees of polycentricity for the 94 urban regions under scrutiny (A),

and focus on three areas with the highest degrees of polycentricity (B, C and D)

3.2 TFP measurement and spatial regression techniques

It is important to note that PURban's algorithmic approach (which loops from the first to the last UC in the database) may lead to situations where (partly) overlapping URs are generated. URs that are composed of exactly the same set of urban centres (leading to exactly the same aggregated indicator values) only featured once. For the remainder of 94 URs, we verify to what extent spatial autocorrelation is present in the data and address this issue by means of spatial econometric modeling. We apply LeSage & Pace's (2009) approach, which argues that the spatial Durbin model is the best point of departure to find out which model is the most likely candidate to explain the data. We test several different specifications of this model and find that the spatial autoregressive model (SAR) is most suitable for our analysis [6].

Similar to Ouwehand et al. (2022), the model we outline a series of factors potentially influencing a region's TFP. The calculation of TFP is the result of predicting the residuals of equation (1a):

$$ln\left(GVA_j\right) = \rho_1 W ln\left(GVA_j\right) + \kappa\ ln\left(K_j\right) + \delta\ ln\left(L_j\right) + \varepsilon_j \qquad \text{(1a)}$$

where the production factors capital ('K') and labour ('L') predict gross value added ('GVA') for each PUR j (thereby including all economic sectors present in the region). In turn, these residuals reflecting TFP are the dependent variable for the main model of this paper predicting regional productivity in URs, given by equation (1b):

$$TFP_j = \alpha_0 + \rho_2 WTFP_j + \alpha_1\ POLY_j + \ \alpha_2\ ln(POP_j) + \ \alpha_3\ DISP_j + \alpha_4\ X_j + \varepsilon_j \qquad \text{(1b)}$$

[6] First, we calculated the Lagrange multiplier robustness tests to examine the presence of spatial correlation in our data. The results point out that spatial effects are indeed present and that a spatial model is to be preferred. We then verify if the spatial Durbin model (SDM), incorporating spatially lagged terms for both independent and dependent variables, could be reduced to either a spatial lag model (SLR), which captures spatial lag in the independent variables, a spatial autoregressive model (SAR), which includes spatial lag in the dependent variables, or a spatial error model (SEM), which includes spatially lagged error terms. Following a likelihood-ratio test, the results indicate that SAR is preferred over SLX, SEM or SDM (we refer to the Appendix for the diagnostics).

Since the production factors of capital and labour are already incorporated in the computation of TFP itself, these are no longer explicitly included in the second model. ρ_2 and ρ_1 (equation 1a) are spatial autoregressive parameters.

W represents the spatial weight matrix, reflecting the structure of the spatial linkages that exists between the observational units. Since we deal with an issue of partly overlapping URs, we used a contiguity-based weight matrix with the following rule: for any pair of PURs i and j, the elements of the W matrix are defined as:

$$W_{ij} = \begin{cases} 1, & \text{in case there is at least one UC that is shared between PURs } i \text{ and } j \\ 0, & \text{otherwise} \end{cases}$$

The remaining factors that we take into consideration are: 'POLY' (the polycentricity index as per section 3.1), 'POP' (the aggregate regional population of all the urban centres in the UR), 'DISP' (the degree to which POP is dispersed across urban centers in the UR, expressed as the number of urban centers in the UR), and 'X' (a set of control variables that were derived based on the literature on regional productivity). The control variables can be classified into three groups controlling for the potential impact of:

(1) human capital ('HUM') (as in Ouwehand et al. 2022), measured here as the number of people employed in knowledge intensive sectors;
(2) infrastructure connectivity ('ACC') (as in Meijers 2007), measured here as the ease with which urban centres in Europe can be accessed by means of different transport modes;
(3) innovation levels ('INNO') (as in Meijers and Burger 2010), measured here as the number of 4.0 patents per 1000 inhabitants of each region (indexed with respect to the ESPON countries' average).

The next section (3.3) provides a detailed list of all data sources and indicators and discusses the data collection procedure in more detail.

Importantly, while our regression model assumes that polycentricity affects regional TFP, causality (if any) may also work in the opposite direction; there is a potential bidirectionality inherent to the structure-productivity relation, as regional productivity may itself also influence a region's growth or its spatial organization (Parr 1979, Ciccone 2002). To estimate to what extent the regressors are exogenous to the model, this paper relies on a generalized spatial two-stage least square regression (GS2SLS). GS2SLS uses instrumental variables (IVs) that are uncorrelated with the error terms to compute estimated values of the predictor(s) (the first stage), and then uses those computed values to estimate a linear regression model of the dependent variable (the second stage). Importantly, the instruments need to fulfil two conditions: they should be relevant (not weak) and valid (exogenous) (see also Meijers and Burger 2010). In case these two conditions are satisfied, SAR regression modelling should be preferred over the GS2SLS estimations as it is a more efficient predictor.

For this purpose and drawing on the approach used in earlier studies (Ciccone 2002, Meijers and Burger 2010, Ouwehand et al. 2022), we compute instrumental variables based on historical population figures. Based on additional coding[7], we calculate historical (for the year 1975) degrees of polycentricity ('POLY_HIST'), regional population sizes ('POP_HIST') and degrees of dispersion ('DISP_HIST') (see also Table 2). The key assumption is that these IVs were instrumental in shaping today's regional spatial structure but that they are *not* related to today's degree of regional economic productivity.

3.3 Data and data collection procedure

Table 2 provides a detailed overview of all indicators used. Many indicators were constructed based on data provided by ESPON, as these data are openly available and provide the most recent evidence at the NUTS3 territorial scale. Importantly, gross fixed capital (CAP) data are

[7] In the GHS-UCDB, the population totals of the urban centres for the year 1975 are calculated using the spatial confines of the 2015 urban centres. In order to improve the accuracy of these historical estimates, we developed our own set of urban centres for the year 1975 by replicating the methodology described by Florczyk et al. (2019b).

only available at the NUTS2 scale. We disaggregated these data to the NUTS3 scale with the help of a covariate variable ‘active enterprises’, using an R package for Bayesian Spatial Disaggregation Modelling (Nandi et al. 2020).

The majority of variables (see Table 2) provide data at the NUTS 3 level. However, since the ‘urban centres’ constitute the unit of analysis for the computation of the degrees of polycentricity, we ultimately need to arrive at economic and control variables for the same spatial scale (only for POP and DISP there is no issue). In an ideal situation, the contours of each UC neatly fall within the contours of one NUTS 3 region. This is the case for many UCs and results in a straightforward allocation of data from the NUTS 3 level to the UC in question. There are, however, also a number of cases in which this ideal situation does not occur: some NUTS 3 regions host two or more UCs, some UCs are located in multiple NUTS 3 regions, and in some situations combinations of both scenarios are present. In order to illustrate how we dealt with these situations, we discuss two examples illustrated in Figure A1 in the Appendix. In general, we use surface proportions to allocate data in case an UC is located in multiple NUTS regions and/or in case multiple UCs are located in one NUTS region. Depending on whether the data reflect absolute values (as with ‘CAP’) or not (as with ‘ACC’), a different value allocation procedure is implemented. Once these data were generated at the level of individual UCs, the values were aggregated to calculate a total indicator score for each PUR. Again, depending on whether values are absolute or relative, a different aggregation procedure was followed (see also Figure A1).

Variable	Abbr	Measurement	Data source	Year of data	Territorial unit of analysis	Missing values*	Mean	Standard deviation	Min	Max	Unit
Total factor productivity	TFP	TFP is the result of predicting the residuals in equation (1a)	/	/	/	/	/	/	/	/	/
Gross value added	GVA	EU27: GVA at basic prices	Eurostat	2018	NUTS3 (2016)	0.5% (Ticino, CH)	109779	58506	22010	272414	Million €
		UK: GVA at current basic prices	Office for National Statistics	2018	NUTS3 (2016)						
Labour	LAB	EU27: Total employment (workplace-based)	Eurostat (Ardeco)	1980-2023	NUTS3 (2016)	5% (regions around Glasgow and Edinburgh + Ticino, CH)	1779	654	104	3494	500 people
		UK: Numbers of persons employed by occupation code	Office for National Statistics	2015 – 2017	NUTS3 (2016)						
Capital	CAP	Gross fixed capital formation by NUTS2 region, disaggregated to the NUTS3 level by using the covariate variable 'active enterprises'	Eurostat (capital) and ESPON database (active enterprises)	2015 (capital), (2014 (active enterprises)	NUTS3 (2013)	0,5% (Ticino, CH)	22671	14215	2007	65974	50000 €
Polycentricity	POLY	Degree of morphological polycentricity	GHS-UCDB, HERE routing API	2015	Urban centre	No	0.53	0.22	0.00	1.00	/
Urban size	POP	Total population of urban centres in the UR	GHS-UCDB				2.86	1.10	1.51	6.55	Million people
Dispersion	DISP	Total number of urban centres in the UR	GHS-UCDB				6	2.6	2	13	/
Human capital	HUM	Indexed indicator reflecting the amount of people employed in knowledge intensive sectors	ESPON database	2016	NUTS3 (2013)	1% (Ticino, CH and Zuid-Limburg, NL)	58.67	110.42	3.36	661.50	/
Infrastructure connectivity	ACC	A composite indicator combining the potential accessibility by road, rail and air, indicating how easy it is for people in one region to reach other European regions	MRS ESPON	2014	NUTS3 (2013)	No	1.82	0.47	0.96	2.76	/
Innovation level	INNO	Indexed indicator reflecting the number of 4.0 patents per 1000 inhabitants	ESPON database	2010 – 2015	NUTS3 (2013)	No	6.52	8.11	0.23	43.19	/
Active enterprises	ACTI	Number of enterprises that are active during at least a part of the reference period	ESPON database	2014	NUTS3 (2013)	No	25185	39901	559	540045	/
Historical polycentricity	POLY_HIST	Historical degree of polycentricity of the UR	Own set of UCs, developed on the basis of GHS-BUILT (1975) and GHS-POP (1975)	1975	Urban centre	No	0.48	0.20	0.00	1.00	/
Historical urban size	POP_HIST	Historical total population of urban centres in the UR					2.50	1.08	1.05	6.55	Million people
Historical dispersion	DISP_HIST	Historical number of urban centres in the UR					6	2.4	1	12	/

Table 2: Overview of variables, data sources and descriptive statistics

* Some of the datasets included missing values, which were addressed as follows: For 'GVA', we consulted Swiss national statistics to retrieve the value for the Ticino NUTS3 region, for 'LAB', we ran an expectation maximization algorithm in SPSS using 'POP' as a covariate variable, for 'HUM' (and the missing 'CAP' value in Ticino) we estimated the Ticino value (and Zuid-Limburg value) by taking the average of the 'HUM' (and 'CAP') values of their neighboring NUTS regions.

4. Findings

The diagnostics, summarized in Table A1 and discussed in the Appendix, indicate that our instruments are relevant and that all independent variables of interest can be treated as exogenous, except for POP. This implies that an SAR estimation would not yield consistent results for this variable and that we need to resort to the GS2SLS regression models in which (only) POP is instrumented. For POLY and DISP, no issues were detected, allowing us to incorporate these variables (and their interaction effects) in SAR regression models.

Table 3 displays these (the SAR and GS2SLS) models. We adopted a stepwise regression approach in which variables were gradually added or replaced. We tested models in which the independent variables of interest were added separately (models 1, 2 and 5), in which two variables were jointly added (models 3, 6 and 7), and in which interaction terms between two variables were included (models 4, 8 and 9). Across all models, the spatial autoregressive coefficients (Rho) are all statistically significant at the 1% level with a positive sign. This indicates that the regional productivity of URs is spatially dependent and has positive externality effects. We now turn to a discussion of the most important findings across the different models.

	SAR				GS2SLS				
	(1) POLY	**(2) DISP**	**(3) POLY+DISP**	**(4) POLY*DISP**	**(5) POP°**	**(6) POP+POLY**	**(7) POP+DISP**	**(8) POLY*POP**	**(9) DISP*POP**
POLY	-0.22(0.08)**		-0.10(0.09)	-0.10(0.09)		-0.48(0.12)***		-0.56(0.12)**	
POP					0.00(0.02)	0.00(0.21)	0.02(0.02)	0.02(0.02)	0.01(0.02)
DISP		-0.02(0.00)***	-0.02(0.00)*	-0.02(0.01)*			-0.04(0.01)***		-0.04(0.01)***
HUM	0.00(0.00)*	0.00(0.00)	0.00(0.00)*	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)
ACC	0.25(0.07)***	0.26(0.07)***	0.26(0.05)***	0.26(0.07)***	0.38(0.06)***	0.38(0.06)***	0.33(0.05)***	0.43(0.06)***	0.33(0.06)***
INNO	0.00(0.02)	-0.03(0.01)**	-0.02(0.01)	-0.02(0.01)	0.02(0.02)	0.02(0.02)	0.00(0.02)	0.00(0.02)	0.00(0.02)
POLY*POP								-0.36(0.11)	
DISP*POP									-0.03(0.01)**
POLY*DISP				-0.00(0.02)					
Constant	0.73(0.05)***	0.72(0.09)***	0.77(0.12)***	0.75(0.12)***	0.57(0.10)***	0.57(0.10)***	0.64(0.10)***	0.51(0.10)***	0.65(0.10)***
R^2					0.49	0.49	0.52	0.51	0.51
Observations°°	94	94	94	94	79	79	79	79	79
Log likelihood	69.34	72.48	73.14	73.15					
Rho	0.74(0.00)***	0.74(0.05)***	0.74(0.05)***	0.74(0.05)***	0.68(0.00)***	0.68(0.00)***	0.69(0.00)**8	0.68(0.00)***	0.68(0.00)***
Region	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed

*** p<0.01, ** p<0.05, * p<0.1 Robust standard errors are shown in parentheses

° POP is instrumented in the GS2SLS regression models.
°° The number of observations in the GS2SLS regression is 79 instead of 94. This is due to the fact that some UCs were not identified based on the 1975 data (resulting in a smaller set of PURs).

Table 3: SAR and GS2SLS regression results

A first set of findings pertains to the three independent variables of interest. POLY is only significant when viewed in isolation (model 1) or when (only) POP is taken into account (models 6 and 8). Its coefficient is always negative, indicating that higher degrees of polycentricity generally correspond to lower productivity levels at the regional level. The latter observation aligns with the results of Brezzi and Veneri (2015), who concluded that regionalized agglomeration economies have not replaced single-centre agglomeration effects.

When introducing DISP to models with POLY, the effect of the latter however turns non-significant, and DISP is always (and negatively) significant in each of the models where it is introduced (in contrast to POP which is never significant in any of the models). This indicates that the relationship between a higher degree of dispersion and its effects on productivity is particularly important here, with more dispersion negatively impacting TFP.

The lack of significance of POP across all models runs counter to what Ouwehand et al. (2022) and Meijers and Burger (2010) found, but it is not entirely unexpected when foregrounding differences in operationalization for this indicator. In our analysis, we preselected urban regions with a minimum total population of 1.5 million (see Section 3.1), in line with the favorable conditions for the development of agglomeration externalities suggested by McCann and Acs (2011). The logic behind this preselection procedure effectuates that it might not make much difference if a PUR's total population equals 1.6 or 1.9 million inhabitants, since both fall within the scope of favorable circumstances.

A second set of findings pertains to the interaction terms. When introducing interaction items separately, we find that none of them are significant, except for DISP*POP (Model 9). The coefficient of this term is close to zero, which implies that the negative impact of DISP on TFP is slightly more pronounced in those regions that are also more populated. This specific interaction effect was not reported by Ouwehand et al. (2022) and Meijers and Burger (2010), and it is somewhat surprising given POP's lack of significance in any of the other models. The interaction term POP*POLY not being significant is also noteworthy, as this relationship was significant (and negative) in both Ouwehand et al.'s (2022) and Meijers and Burgers' (2010) work, which implied that the influence of polycentricity is contingent on the size of urban regions.

A third set of findings pertains to the control variables. We find a positive impact of both HUM and ACC. These findings are in line with our expectations. Since high-value and high-growth industries are considered relevant factors in influencing regional productivity (Dogaru et al. 2014), it should not come as a surprise that the number of people employed in knowledge-intensive sectors (HUM) has a strong positive impact on TFP. Likewise, we expect that infrastructural connectivity and resulting accessibility at the European level (ACC) positively impact the efficiency and intensity with which a region can organize its production internationally[8]. Somewhat unexpectedly, high levels of regional innovative or technological capacity (reflected by INNO) do not seem to impact TFP in any of the models. While there are no multicollinearity issues (see above), a potential reason may be that the number of people employed in knowledge-intensive sectors tends to be higher in urban regions with high technology levels, meaning that HUM may absorb some of the variation in INNO.

[8] Bear in mind that this indicator mainly reflects the external accessibility of a region (as explained in Table 2) and, to a lesser extent, its internal logistic efficiency and the intensity with which a region can organize its production. The latter may be important for the regional organization of production but was not available for our analysis.

5. Discussion and conclusions

In exploring the structure-productivity relation of 94 European URs, we adopted a consistent quantitative approach to sketch a broad picture of how regional spatial structure (measured in terms of polycentricity, dispersion and size) and economic productivity are related at the level of urban regions.

In general terms, and in line with most earlier studies discussed in Section 2.3, we find no empirical evidence for the often-hypothesized positive impact of urban polycentricity on regional economic productivity in Europe. Rather, we observe either a negative or no effect of POLY on TFP, depending on the inclusion of additional spatial structure variables (POP and DISP) in the models. The combined observations of POLY negatively influencing TFP (models 1, 6 and 8) and of DISP negatively influencing TFP (models 2, 3, 4, 7 and 9) both hint at the continuing importance of single-centre agglomeration effects.

Besides this, our outcomes also highlight the importance of developing analytical frameworks that consider the (interaction) effects of several spatial structure variables (next to POLY). As our analyses illustrated, including DISP in the models helps qualifying the (negative) effect of POLY on TFP, since DISP appears as a stronger (negative) predictor of TFP than POLY. While a negative impact of dispersion on productivity was hypothesized by Ouwehand et al. (2022) and Meijers and Burger (2010, for the case of US metropolitan areas), both studies did not find any significant relationship between dispersion and productivity. It should be noted, however, that DISP is operationalized differently compared to the indicators used in these aforementioned studies: whereas the latter reflect the extent to which the population of a region is localized *outside its urban cores*, our measure considers the degree to which regional population is dispersed across urban centres. Since our URs do not coincide with administratively defined regions (and we therefore can not calculate a share of population localized outside the UCs but within a regional boundary), we resorted to this operationalization of dispersion. We also verified the effects of an alternative take on (spatial) dispersion that incorporates geographic distances between the UCs: the median distance between the central UC and all other UCs in the UR. We found no significant effect of this indicator in any of the models, which may be explained by the fact that we already preselected those URs that have a 'favorable' commuting distance of 45 minutes. In other words, within our set of URs, productivity is not significantly impacted when UCs are more strongly connected by means of road infrastructure. These examples nonetheless highlight that future research may focus on this aspect in particular, and explore to what extent different dispersion measures may impact the results.

As suggested in the previous paragraph, our choice to conduct our analysis for regions that do not coincide with administratively defined regional boundaries has a number of important implications. A clear positive implication is the fact that this approach delineates regions in a 'bottom-up' manner, by systematically selecting those spatial patterns that are deemed favorable for regionalized agglomeration economies to develop (as explained in Section 3.1), but without being restricted to administratively defined regionalizations. For example, in the case of Belgium, the PURban algorithm identified an UR connecting UC Brussels (largely corresponding with the Brussels Capital Region) with UCs in the Flemish administrative region (e.g. Antwerp) and the Walloon administrative region (e.g. La Louvière). As demonstrated by van Meeteren et al. (2016b), these cross-border connections indeed play important roles in the connectivity field of the Brussels Capital Region in terms of commuting flows. In other words, when adhering to administrative regions (OECD TL2 in this case) as the unit of analysis (as in Ouwehand et al. 2022), important regional dynamics pertaining to economic productivity (and polycentric development) are arguably overlooked.

On the other hand, a clear drawback of working with uniquely defined regionalizations involves the *post hoc* coordination between those territorial units and those at which the variables of interest have been collected. Although the fact that we work with UCs allows us to attune these spatial units with the most fine-grained territorial scale at which harmonized EU-wide data is available (the NUTS 3 level), the allocation procedure that we developed to this end comes with a number of drawbacks. As explained in Section 3.3, the available information at the NUTS 3 level is apportioned to the UCs on the basis of the surface area covered. A crucial assumption throughout this process is that, within each NUTS 3 level, the data captured by the variables in Table 2 is allocated to the territories of the UCs only. In other words, we assume that all (economic) activity measured is concentrated within the confines of these UCs. Evidently, this assumption will result in an upward bias of estimates at the UC level, since there are a number of NUTS 3 regions in which substantial levels of urbanization are located *outside* the confines of the UCs. In fact, on average, 40% of the total population of the NUTS 3 regions in our analysis is located outside the confines of an UC (or multiple UCs). In future research, this effect could be moderated by developing a procedure that allocates in terms of nighttime light data or population shares instead of surface area covered.

The above issues raise further pertinent questions, a first one of which pertains to the usefulness of invoking the degree of urbanization framework in the context of understanding the productivity effects of spatial structure at the regional scale. As outlined above, we see clear advantages in defining urban territories using non-administrative, granular data (as in GHS-UCDB), i.e.: a higher comparability across regional or national contexts (comparing 'likes with likes'), more appropriate delineations for policies targeting specific urban geographies, and more appropriate delineations that advance scientific understandings about fundamental urban (and regional) questions (Duranton 2021) such as agglomeration economies. However, in order for the GHSL framework to be more usefully invoked in spatial-econometric analyses, we believe it should incorporate a wider range of useful socio-economic variables at that territorial level (eliminating the need for post hoc imputation of data at different scales).

While the latter suggestion would arguably also improve the policy relevance of the degree of urbanization concept, deriving tailored, region-specific, policy recommendations remain difficult, since the ‘bottom-up’ (and often cross-border) regions that we work with generally do not correspond to the territorial units at which regional-economic decision-making processes take place. Additionally, since spatial-econometric models cannot provide the in-depth detail of case studies, deriving tailored recommendations for specific regions is not the purpose of this research. What our systematic quantitative approach does allow for, is to sketch a broad picture of how urban-regional structure and economic output are generally related at the European scale. Translated to policy, we find evidence for a continuing importance of single-centre agglomeration benefits.

To conclude, the predominant conceptual focus on morphological polycentricity in previous European analyses (see Table 1) does not exclude the possibility that a functional approach would lead to different outcomes (Vasanen 2012). In fact, adopting a functional lens on polycentricity may align better with a focus on economic productivity, as “(i)t is connectivity that makes a network, not mere physical proximity: being adjacent to communications infrastructure or to the facilities of a place does not ensure access (…) Interaction, complementarity and some institutional action ‘for the region’ underpin the use of the PUR concept as a policy, and so should figure in definitions and measurements” (Hague and Kirk 2003, p. 21). ESPON (2007, p. 220) also criticized the morphological approach as reductionist when arguing that the use of demographic size as the primary indicator of polycentricity refers to a limited understanding of urban ‘systems’: “urban geographers have shown the rank-size analysis is only efficient to qualify the hierarchy of a set of cities but not a system of effective relations. (…) it is at best only a very indirect indicator of how an urban system might work”. While these and other authors have repeatedly criticized this morphological conception, studies at extensive territorial scales such as the pan-European level continue to draw on this approach due to a lack of appropriate data (like commuter flows or links between firms) at a European-wide scale. Instead of arguing that one therefore has no option but to resort to morphological indices, one might in turn question whether, in the absence of sound relational data, additional analyses will significantly increase our knowledge on the issue.

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