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Productivity of the EU metropolitan areas: Trends, spatial analysis and convergence

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Abstract

Metropolitan areas are considered as major drivers of economic growth due to the significant productivity gains resulting from their agglomeration economies. This article examines the labour productivity developments of the EU countries at the level of metropolitan regions (or functional urban areas) and tests the hypotheses of convergence and spatial autocorrelation among them during the decade 2010-2019. The findings show that the frontier metropolitan regions are largely located in the central and western Europe, while the laggard ones are found in the southern and eastern Europe. Besides, the mega (or very large) metropolitan areas are found to be more productive than the smaller ones. Nonetheless, smaller metropolitan areas, especially those having less than one million inhabitants, present higher productivity growth than the larger ones. In the same period, we find the existence of slow productivity convergence among the EU metropolitan regions, but divergence when metropolitan regions belonging to the eastern Europe are excluded, as the latter ones have the greatest dynamism. Furthermore, the productivity clustering effects have been considerably contained during the study period. Based on the local indices of spatial autocorrelation, in 2019, the largest clustering effects are found in the most productive (western and central) metropolitan regions, but most of these effects prevail in the eastern metropolitan regions, signifying their impact on productivity growth. These findings suggest the importance of designing place-based development policies to enhance productivity and diminish inequalities of developed EU regions with those left behind.

Keywords: Productivity; metropolitan regions; inequalities; clustering; European Union.

1. Introduction

The improvement of productivity has a durable effect and determines the living standards and well-being conditions in a country and the growth rate of its economy at a long-term horizon. At the same time, the treatment of the productivity slowdown and the increasing disparities among countries and regions are regarded as policy priorities for the European Union (Rincon-Aznar et al., 2014, Juncker et al., 2015, Van Ark and Jäger, 2017). On the one side, productivity slowdown is a lingering economic concern, as it remains a critical source of prosperity, but its full exploration and interpretation is still missing, especially at the local level. On the other side, productivity convergence among regions at the national and European levels is crucial for the sustainable and resilient economic development for several reasons.

First, productivity and its convergence across regions and, especially, local areas can facilitate a stable economic growth and sustainable development, by narrowing the productivity gaps, thus, leading to a more balanced and equitable distribution of economic activities across space. This is particularly important in the context of metropolitan (or metro) areas, which are less developed or left behind, where productivity disparities can exacerbate within-country and intra-regional inequalities and hinder the overall economic progress. Additionally, productivity convergence can promote the efficient allocation of resources and the optimal utilisation of factors of production among and within regions, thereby, enhancing the total economic efficiency.

Furthermore, productivity convergence is essential for promoting innovation and technological diffusion across regions. As technological development has rendered the interaction and communication between and within regions more convenient, productivity convergence can facilitate technology spillovers and diffusion effects, contributing to the overall technological advancement and economic growth. This process is typically depicted by the concept of β-convergence, which refers to the faster growth rate in regions with a backward technological level, resulting in the narrowing gap among regions over time (Barro, 1991; Barro and Sala-i-Martin, 1992). In a nutshell, productivity and its convergence across regions constitute crucial metrics, beyond the standard metric of Gross Domestic Product (GDP), for promoting economic growth, efficiency and innovation, reducing disparities, enhancing competitiveness, and facilitating technological diffusion and knowledge spillovers.

Although several studies in the scholarly literature have examined the regional disparities and convergence among the productivity of the EU regions from different aspects, there is scarcity of research in treating these issues at the level of metropolitan areas (Longhi, 2008; Dijkstra et al., 2013). This higher level of spatial analysis can arguably address measurement issues and more accurately account for sources of productivity gain due to agglomeration effect and spatial variations in productivity. In turn, it can help us understand and interpret related trends and patterns in a very large and economically diverse spatial entity like the European Union.

Metropolitan-level policies are not usually coordinated and do not rely on productivity criteria, but rather on traditional economic development metrics, such as new capital investments and new job positions (OECD, 2023). At the same time, several EU policies, such as those originating from the Cohesion fund, may have an uneven impact on the regions of member-states, national policies may unevenly affect all regions of a country (Bachtrögler et al, 2020; Caro and Fratesi, 2022; Santos et al., 2023), while regional policies may have a varying influence on the urban areas within an administrative region. Besides, productivity diffusion or clustering effects on nearby metropolitan areas due to shared resources are not typically considered, albeit they can have a profound impact on their economic performance, according to the local characteristics and policies at the subnational level.

Given the scarcity of productivity statistics at the metropolitan level, this article investigates the main trends, convergence and clustering effects among the EU metropolitan regions (or FUAs), in terms of their labour productivity, as defined by the ratio between the GDP and the number of workers, based on the OECD city statistics. The period of the analysis refers to the decade 2010-2019, namely, the period after the shock of the great recession in 2008-2009 and before the shock of the COVID-19 pandemic in 2020, which significantly adversely affected the economy, productivity, and labour markets across the EU countries (Shibata, 2021; Bloom et al., 2023).

As far as the organisation of the article is concerned, Section 2 describes the main labour productivity trends, identifying the productivity frontier and laggard metropolitan regions in the EU, as well as those metro-regions presenting the largest and smallest productivity growth rates. Section 3 examines the relationship between labour productivity and the (population) size of FUAs, and the productivity convergence among the EU metro regions, including the impact of the ex-communist, eastern metro regions in the convergence process. Section 4 uses the Moran's index of

spatial autocorrelation to analyse the productivity clustering (or dispersion) among the EU metropolitan regions. Section 5 concludes and provides policy implications about the enhancement of the EU productivity at the metropolitan level.

2. Productivity trends in the EU metropolitan regions

The current study employs a dataset referring to 264 metropolitan EU regions, defined as Functional Urban Areas (FUAs)[1] according to the corresponding OECD database (OECD, 2013). Table 1 reports the descriptive statistics of the labour productivity variable at the beginning and final year of the study period, i.e., in 2010 and 2019. These metrics indicate the slow pace of average productivity growth, that is, a total increase by almost 3.5% or 0.35 per year. At the same time, the standard deviation of labour productivity was substantially increased during the study period, from 19,874 $/worker to 25,200 $/worker, signifying the increased variation (inequalities) of productivity among the EU metropolitan regions. In particular, we observe that the maximum value of labour productivity was more than doubled during 2010-2019, i.e., from 153,911 $/worker to 352,915 $/worker.

Table 1 Descriptive statistics of the labour productivity (GDP per worker in USD, constant prices, constant PPP, base year 2015) in the EU metropolitan regions in 2010 and 2019

Metric	2010	2019
Average	82,553.6	85,425.7
1st Quartile	73,373.0	74,244.0
2nd Quartile	83,800.5	83,864.5
3rd Quartile	93,675.5	91,562.5
Standard Deviation	19,874.0	25,200.2
Minimum	24,022	29,931
Maximum	153,911	352,915

[1] The functional urban areas (FUA) constitute a new definition of urban areas, based on their economic functioning, rather than their administrative boundaries, thus, allowing for better comparisons of economic performance across countries and regions. Specifically, each FUA corresponds to a spatial economic entity characterised by densely inhabited urban core and hinterlands, namely, working catchment areas of urban labour markets, which are highly integrated with the urban core.

Figures 1 and 2 map the labour productivity in the EU metropolitan regions at the beginning and final year of the study period, i.e., in 2010 and 2019. Each map groups metro areas to five (5) distinct groups according to their productivity level. The bin ranges designating each group in these maps are expressed as 'natural breaks' according to the Jenks optimization method (Jenks, 1967), which is a data clustering method designed to determine the best arrangement of values into different classes. This method minimises the average deviation of each class from the class mean, while it maximises the deviation of each class from the means of the other groups; hence, it reduces the variance within classes and maximises the variance between classes. Furthermore, Figures 3 and 4 present the top-10 and bottom-10 EU metropolitan regions in labour productivity in years 2010 and 2019, respectively. Also, Figure 5 shows the top-10 and bottom-10 EU metropolitan regions in terms of labour productivity growth during 2010-2019.

The empirical findings reveal some clear regional patterns both between and within the EU countries. By and large, large and/or capital metro areas mostly located in the central and western Europe, such as Luxembourg, Dublin, Paris, Brussels and München (Munich) (in 2010) are included in the top-10 productive ones, as represented by the blue coloured group. In 2019, metro areas from the northern and eastern EU also appear in the list of the top-10 productive regions, such as Warszawa (Warsaw) and Stockholm. Other smaller-size metro areas are also included in the most productive ones, such as Cork, Wolfsburg, Groningen (in 2010), Antwerpen (in 2010), Limerick (in 2019) and Ingolstadt (in 2019). At the same time, considerable interregional disparities in labour productivity are observed among Paris and the remaining metro areas of France, Warszawa (Warsaw) and the remaining metro areas of Poland, and Bucuresti (Bucharest) and the remaining metro areas of Romania.

Therefore, it can be argued that not only the size (which will be separately examined in the next Section) but also the location of metropolitan areas (in the EU, in their own country and nearby other ones) as well as other structural characteristics may play a significant role in their productivity performance. In particular, the location of many high-productivity metro areas across the so called 'blue banana' development zone (between London and northern Italy) reveals a core-periphery pattern and verifies the importance of the geographical concentration of diverse specialised industries accommodating the bulk of value-added trade in Europe (Krugman and Venables 1995; Tsekeris, 2021). Nevertheless, this spatial (zone) pattern of productivity is much less

evident in 2019 (Figure 2) compared to 2010 (Figure 1), as productivity gains change over time, focused on specific clusters and according to the positioning/supply role, size and technology of industries (Cainelli et al., 2018). The varying regional dynamism of the EU metropolitan regions is analysed in the next section. The laggard EU regions are largely those situated in the eastern and southern countries of Europe. Specifically, the 10 least productive metropolitan areas are found to be located in the eastern bloc of the EU countries, except for Thessaloniki (Greece) and Braga (Portugal) in 2019. The gap between the top-10 and bottom-10 productive metro areas have remained basically the same during the study period, as the former ones were on average about 3.7 and 3.5 more productive than the latter ones in 2010 and 2019, respectively.

Regarding the dynamism of the EU metropolitan areas, the best performing regions in terms of productivity growth during 2010-2019 belong to the eastern bloc of Europe. Specifically, the metro areas having the highest productivity growth, except for the first two (Cork and Limerick in Ireland), are situated in Romania (Craiova, Cluj-Napoca, Iasi, Constanta, Bucuresti), Poland (Nowy Sacz, Rzeszów) and Lithuania (Kaunas). In opposite, the metro areas exhibiting the lowest productivity growth are mostly situated in southern Europe, such as in Greece (Athina, Thessaloniki) and Italy (Perugia, Taranto, Roma), and in central Europe, such as in the Netherlands (Groningen, 's-Gravenhage) and Luxembourg. In particular, during the study period, the top-10 performing metro areas were growing with an average rate of 55%, whereas the bottom-10 performing metro areas were shrinking with an average rate of -9.6%. It is also stressed that productivity growth of the most metro regions of central-western, northern and southern Europe is around or (well) below the EU average (9.3%).

These regional differences imply that a process of convergence among the more developed and less developed (eastern) metro areas is under way after the transition of the ex-communist countries to the market economy. In addition, the present outcomes are largely consistent with those of other studies in the literature (Männasoo et al., 2018; Kijek and Matras-Bolibok, 2020; Tsekeris and Papaioannou, 2021), in the sense that the productivity in catching-up regions with low levels of productivity (particularly in the eastern EU) grew faster than in those with high levels of productivity. The above detected patterns of productivity growth manifest the existence of considerable interregional disparities within the EU, signifying a multi-speed catching-up process among the EU metro regions. The next section examines in more detail this convergence process with the use of a β (beta) convergence analysis.

Figure 1 Labour productivity (GDP per worker in USD, constant prices, constant PPP, base year 2015) in the EU metropolitan regions, 2010

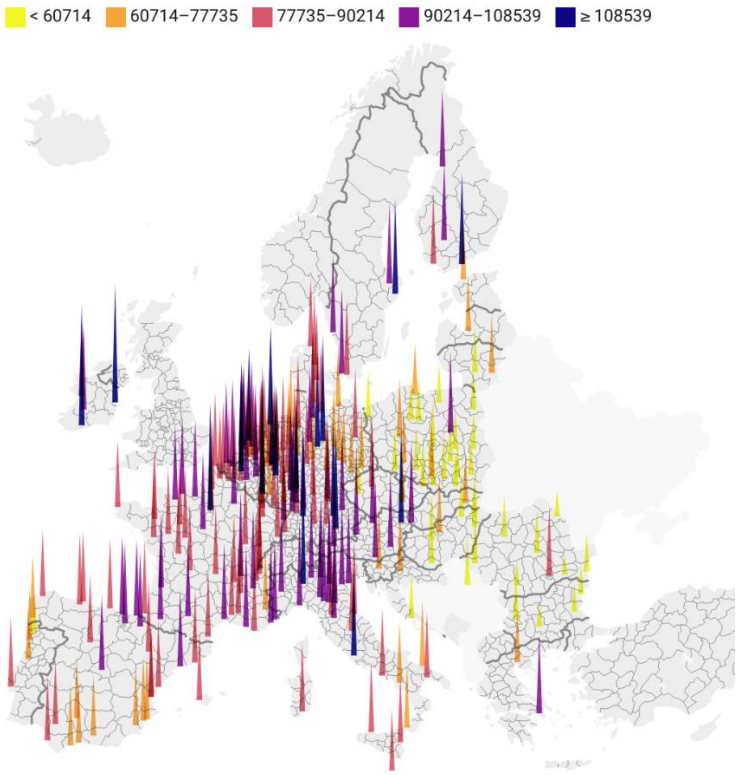


Figure 2 Labour productivity (GDP per worker in USD, constant prices, constant PPP, base year 2015) in the EU metropolitan regions, 2019

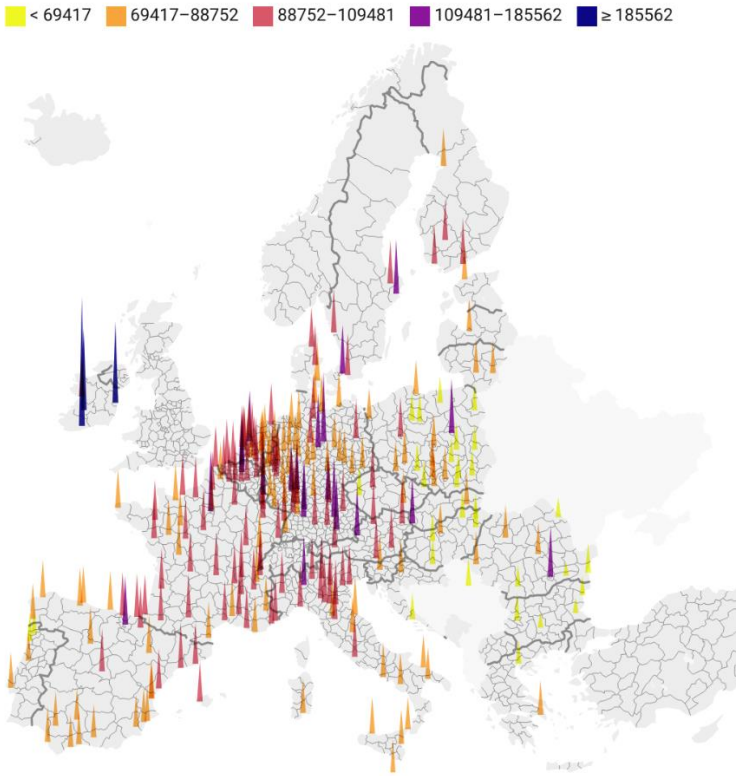
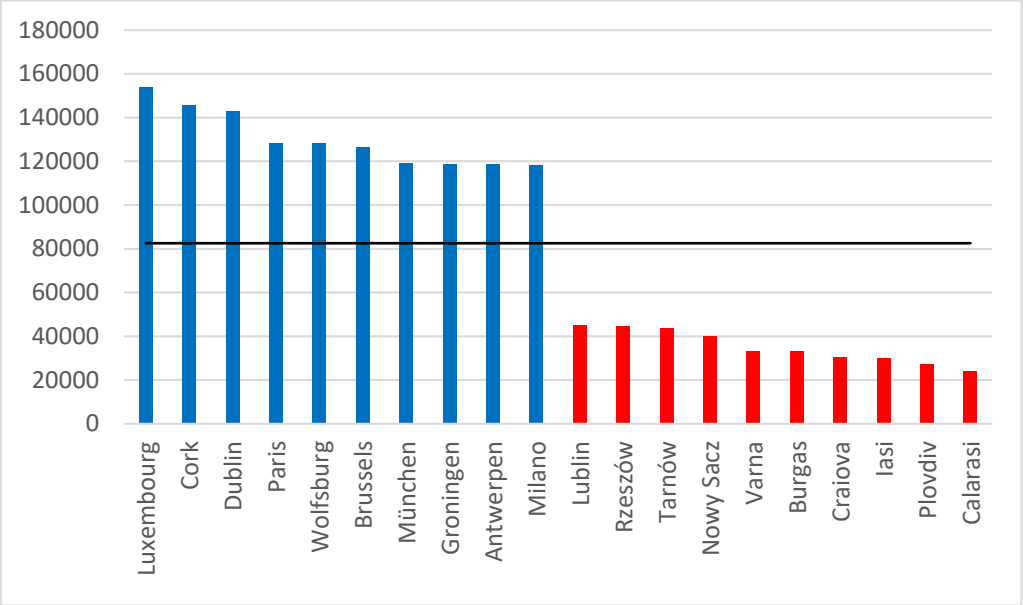
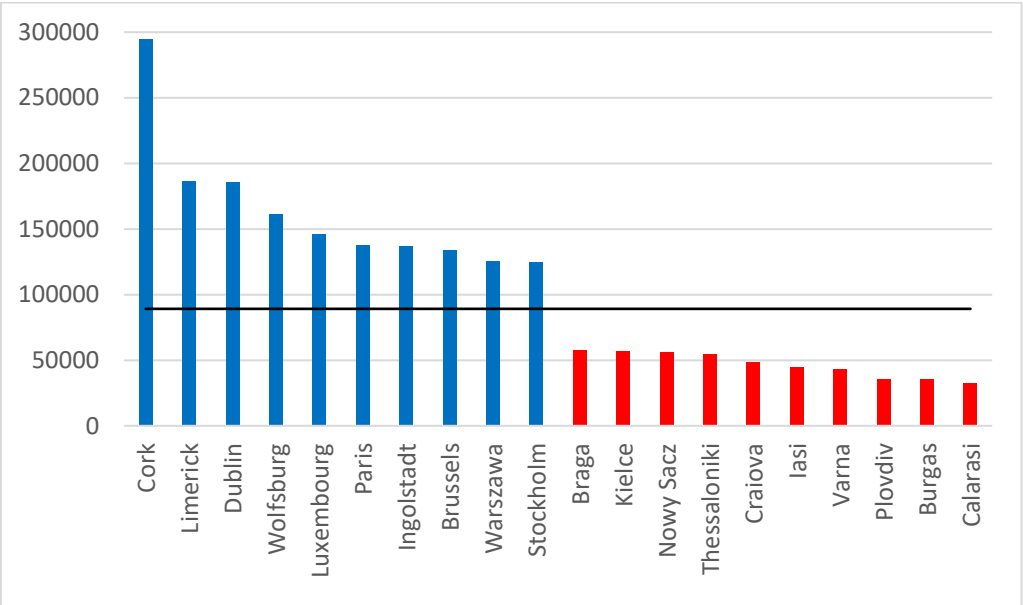


Figure 3 Top-10 and bottom-10 EU metropolitan regions in labour productivity (GDP per worker in USD, constant prices, constant PPP, base year 2015), 2010



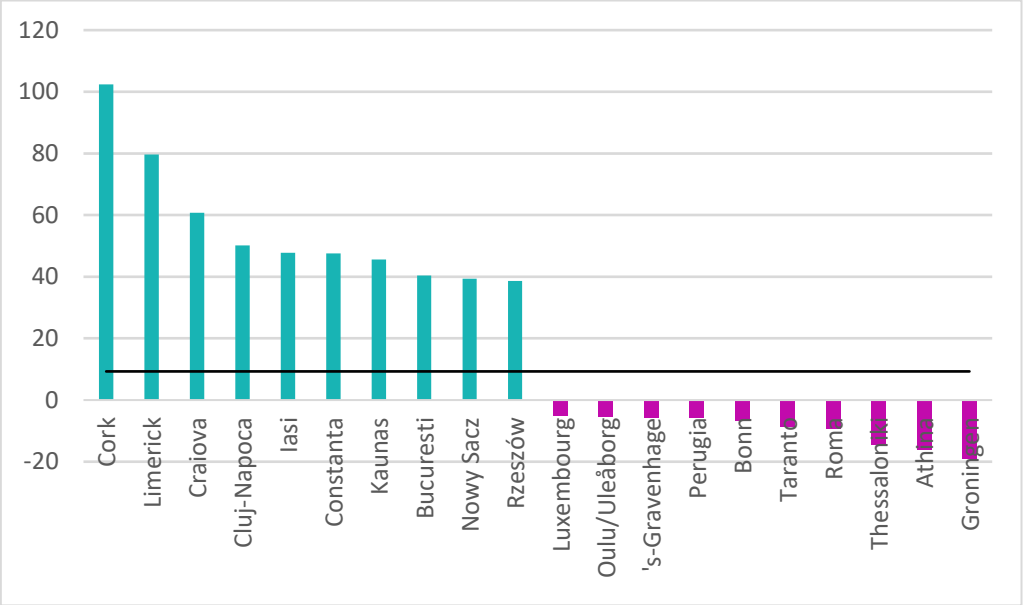
Note: The solid line corresponds to the average level of labour productivity in the EU regions.

Figure 4 Top-10 and bottom-10 EU metropolitan regions in labour productivity (GDP per worker in USD, constant prices, constant PPP, base year 2015), 2019



Note: The solid line corresponds to the average level of labour productivity in the EU regions.

Figure 5 Top-10 and bottom-10 EU metropolitan regions in labour productivity growth (%), 2010-2019



Note: The solid line corresponds to the average level of productivity growth in the EU regions.

3. Labour productivity, metropolitan size and convergence

This section first examines in more detail the relationship between the size of metro areas and labour productivity. Figure 6 illustrates the level of productivity (in 2019) and Figure 7 shows the productivity growth during the study period, by population size of EU metropolitan regions. For the sake of analysis, the population size has been separated into six distinct bin ranges. As it is clearly observed in Figure 6, labour productivity increases steadily with the size of metropolitan region, until reaching 2 million inhabitants, and then basically remain the same. This outcome shows the productivity-enhancing impact of the metropolitisation of regions and is consistent with the empirical literature. For instance, Ahrend et al. (2017) found that the doubling of population in large metropolitan areas within the OECD is associated with a total increase (12%) in average labour productivity, originating from both selection and agglomeration effects. These effects usually arise through learning, knowledge sharing, and specialization benefits.

Figure 6 Labour productivity (GDP per worker in USD, constant prices, constant PPP, base year 2015) by population size of EU metropolitan regions, 2019

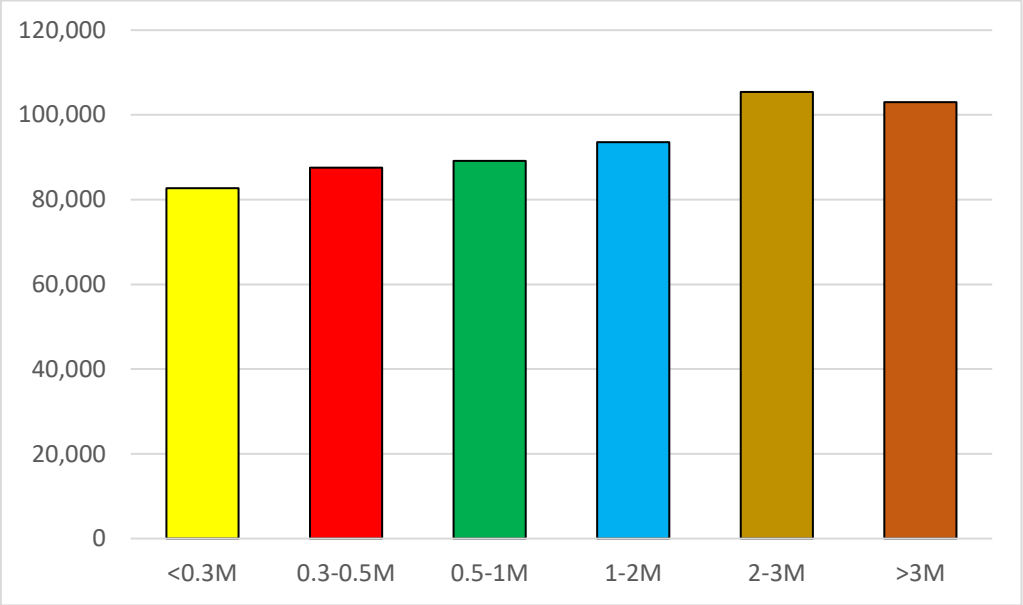
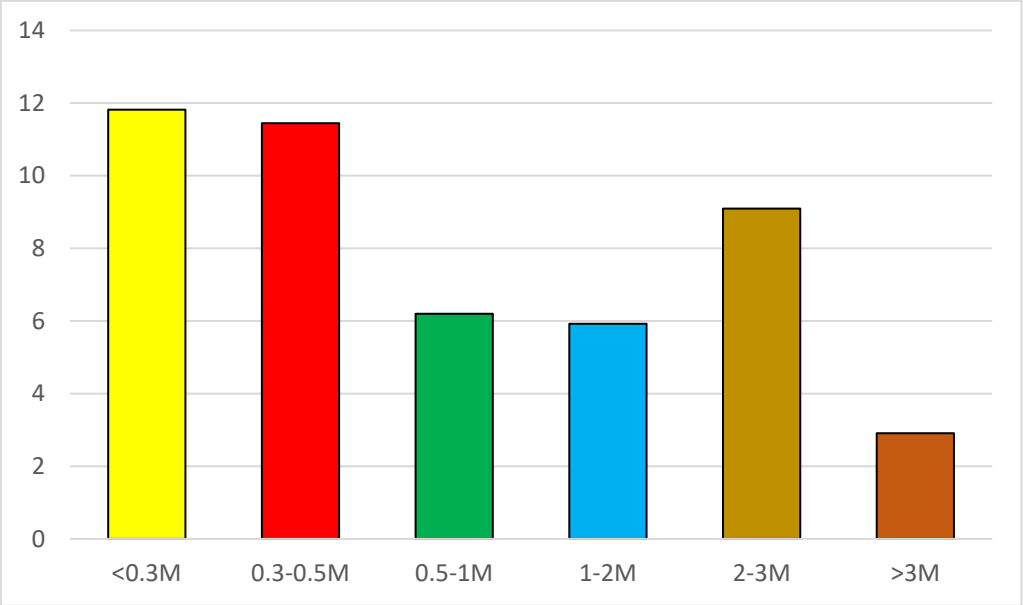


Figure 7 Labour productivity growth (%) by population size of EU metropolitan regions, 2010-2019



In contrast with the level of productivity, the productivity growth is not consistently observed in large cities or metro areas (Figure 7). Specifically, during 2010-2019, the small (below half million inhabitants) and very small (lower than 0.3

million inhabitants) metro areas present the highest (>11%) productivity growth, while the very large metropolitan regions (exceeding 3 million inhabitants) exhibit the lowest (<3%) productivity growth. This outcome verifies that the dynamism of large metropolitan regions cannot be considered as outperforming that of the smaller ones (Dijkstra et al., 2013) and suggests that the impact of agglomeration economies on the productivity of large cities is not linear and non-monotonic, due to the existence of variable returns to scale, i.e., diseconomies of agglomeration arising from reduced housing affordability, increased congestion, pollution etc.

In order to further understand the dynamics and heterogeneity of productivity growth, the catch-up or convergence hypothesis is tested for the whole sample of EU metropolitan regions as well as for a sample that excludes metropolitan regions of (the later entrant) eastern European countries. In brief, let $y_{i,t,t+T} \equiv log\left(y_{i,t+T}/y_{i,t}\right)/T$ be the average annual growth rate of productivity of metropolitan region i between the initial year t and the final year $t+T$, T be the length of the time period of analysis, and $log\left(y_{i,t}\right)$ the logarithm of each metropolitan region's i initial productivity at year t. We estimate the regression:

$$y_{i,t,t+T} = \alpha - \beta\, log\left(y_{i,t}\right) + \varepsilon_{i,t} \tag{1}$$

If we find that β is positive and statistically significant, then, it is considered that the sample metropolitan regions show (absolute or unconditional) β-convergence during the given time period (Barro and Sala-i-Martin, 1992; Bernard and Jones, 1996). Subsequently, the speed of convergence β_s can be calculated as follows:

$$\beta_s = \frac{\ln(1+\beta\, T)}{T}, \tag{2}$$

The estimate of β_s allows us to calculate the time it takes to reduce the interregional productivity gap by half ($t_{0.5}$), as follows:

$$t_{0.5} = \frac{\ln 2}{\beta_s} \tag{3}$$

Figure 8 Diagrammatic representation of the (unconditional) beta (β) convergence of labour productivity (GDP per worker in USD, constant prices, constant PPP, base year 2015) among the EU metropolitan regions, 2010-2019

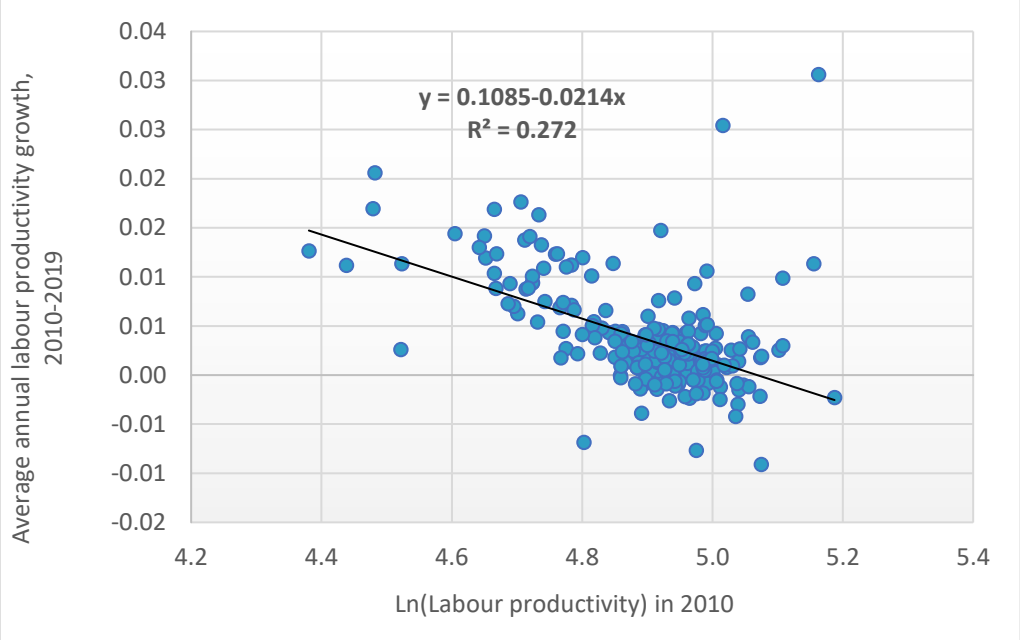


Figure 9 Diagrammatic representation of the (unconditional) beta (β) convergence of labour productivity (GDP per worker in USD, constant prices, constant PPP, base year 2015) among the EU metropolitan regions when omitting the eastern European regions, 2010-2019

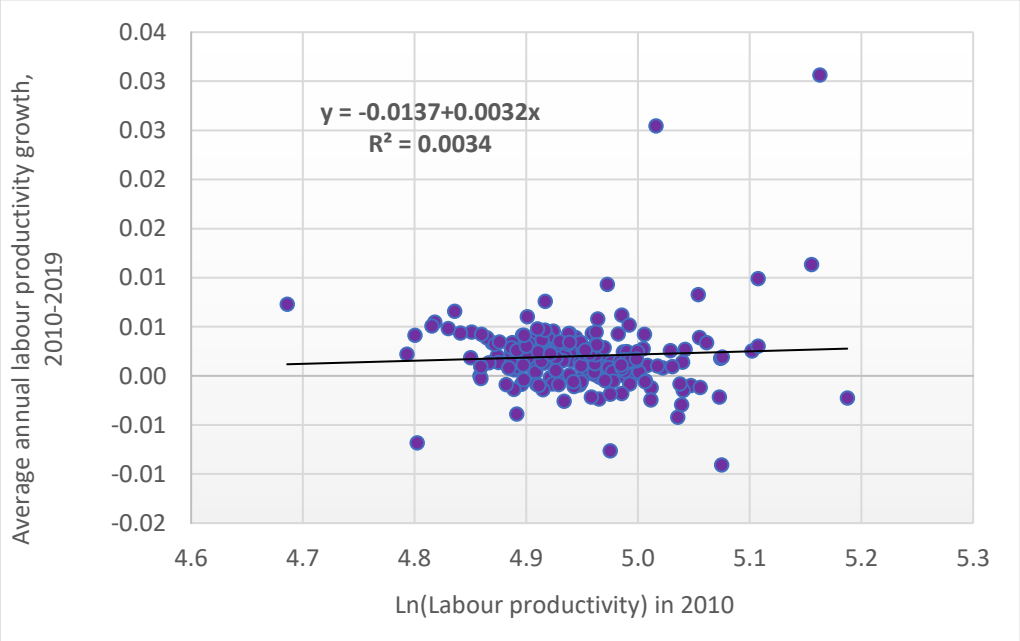


Figure 8 indicates the existence of a clear trend of convergence across the entire sample of the EU metropolitan regions during 2010-2919, as the β coefficient in equation (1) has the expected (positive) and statistically significant (at the 0.01 significance level) sign, that is, β=0.021. In turn, the speed of convergence is positive over the study period and equal to β_s=0.019. These results imply that it should take $t_{0.5}$ ≈36 years to reduce the inter-metropolitan regional technology gap in the whole EU by half. When excluding from the sample of metropolitan regions those situated in the eastern bloc of EU countries (Figure 9), the convergence hypothesis is not accepted. More specifically, this convergence is negative, implying a divergence process, as reflects the value of β coefficient (β=-0.0032), which is statistically nonsignificant at both levels of confidence 1% and 5%.

The latter outcome reassures that the transition from centrally planned to market-based economies has stimulated catch-up growth of central-eastern European countries, largely contributing to the EU convergence process (Bisciari et al., 2020; Pina and Sicari, 2021). Hence, the metropolitan catching up process, which had been earlier identified (Longhi, 2008), was essentially driven by the eastern metro areas during the 2010s, given also the fact that southern European countries lost ground, especially after the global financial crisis. It is characteristically mentioned that the metropolitan regions of Athens and Thessaloniki display the most negative productivity growth (-14.6% and -16.2%, respectively), following the deep and persistent recession of the Greek economy during the 2010s, but also the population decline, in contrast with the increasing share of people living in metropolitan regions in other OECD countries (OECD, 2023). These findings further support previous empirical evidence at the regional level (OECD, 2018; Tsekeris and Papaioannou, 2021) that most of the growth dynamics in the so called 'Old Europe' are concentrated at the frontier regions, whose steady-state growth path stays ahead of the laggard ones, with insubstantial catch-up effect.

4. Spatial patterns of metropolitan productivity

Following the identification of distinct spatial patterns regarding the location, the size distribution, and between- and within-country disparities of metropolitan productivity, this section focusses on local pattens pertaining to the spatial autocorrelation of labour productivity between metro areas. The local Moran statistic was suggested in Anselin

(1995) as a way to identify local clusters and local spatial outliers. The Moran's I local index offers a metric of the spatial autocorrelation based on both features of geographical location and values. In the present context, this statistic is used to identify metropolitan regions that differ significantly from those expected under the null hypothesis that there is no association between the productivity value observed at the location of a metro area and the productivity values observed at nearby metro areas. Given the geographical location of metropolitan regions and the associated productivity values, the Moran's I local index evaluates whether the pattern expressed is clustered, dispersed, or random. Specifically, when the z-score indicates statistical significance, rejecting the null hypothesis, a positive Moran's I index value indicates tendency toward clustering, while a negative Moran's I index value indicates tendency toward dispersion.

Let us denote the inverse of geographical distance (calculated through the longitude and latitude coordinates of the corresponding metropolitan centroid) between two metro areas i and j with row-standardised weights, that is, the sum of all spatial weights, $S_0 = \sum_i \sum_j w_{ij}$ equals the number of observations (metropolitan locations) n of labour productivity values. Then, the Moran's I statistic can be expressed as:

$$I = \frac{\sum_i \sum_j w_{ij} z_i z_j}{\sum_i z_i^2}, \tag{4}$$

where $z = y_i - \bar{y}$ denotes the deviations (of region's i) from the mean productivity value (during a given year period). The corresponding local Moran statistic would consist of the component in the double sum that corresponds to each observation i, that is:

$$I_i = \frac{\sum_j w_{ij} z_i z_j}{\sum_i z_i^2} \tag{5}$$

In equation (5), the denominator is fixed and, hence, can further be ignored. For simplicity, we can denote the denominator term as c, so that the local Moran expression becomes $c \cdot \sum_j w_{ij} z_i z_j$, or, after rearrangement:

$$I_i = c \cdot z_i \sum_j w_{ij} z_j \tag{6}$$

In equation (6), the local Moran statistic is expressed as the product of the value at location i with its spatial lag, i.e., the weighted sum of the values at neighboring locations. An index value of Moran's I > 0 indicates positive spatial correlation and the greater the value, the stronger the spatial correlation. The significance of local Moran's I is assessed through the conditional permutation method, based on a null hypothesis of spatial randomness (Anselin, 1995). According to this method, a reference distribution for the local Moran's I is estimated by randomly permuting the values over the n locations. This distribution is used to calculate a p-value $p = (R + 1)/(M + 1)$, where R is the number of times the local Moran's I is calculated based on the permuted datasets (equal to or larger than the observed local Moran's I) and M equals the number of permutations (set by default as 999).

At the beginning of the study period (year 2010), we observe that a considerable number of metropolitan regions, i.e., 118 or 45% of them, present statistically significant (at the 95% confidence level) spatial autocorrelation effects, the largest and most of which are positive, denoting clustering (agglomeration) patterns, particularly in the central western and the eastern EU metro areas (Figure 10). The number and magnitude of significant spatial autocorrelation effects is profoundly reduced at the end of the study period (year 2019). These are mostly concentrated at the central and western Europe (Figure 11), and correspond to less than half (i.e., 56 or 21% of the total) of the number of metropolitan regions with significant spatial autocorrelation in 2019.

Figure 12 shows in more detail the EU metropolitan regions having significant spatial autocorrelation of their labour productivity values with those of neighboring regions in 2019. The metropolitan regions showing the largest clustering in labour productivity are situated in Ireland (Cork, Limerick, Dublin) and, to a lesser extent, in central Europe (Brussels, Antwerpen, Luxembourg) and southeastern Europe (Burgas, Varna, Plovdiv, Calarasi). Only three capital metropolitan regions situated in eastern Europe present significantly negative spatial autocorrelation, i.e., dispersion among large positive and negative productivity values: Warszawa (Warsaw), Bucuresti (Bucharest), and Bratislava. Last, Figure 13 indicates the existence of a positive and statistically significant (at the 95% confidence level) relationship between metropolitan productivity and the corresponding Moran's index of spatial autocorrelation, verifying the positive role of productivity clustering at the subregional level of analysis.

Figure 10 Moran's local index of spatial autocorrelation of labour productivity among the EU metropolitan regions, 2010

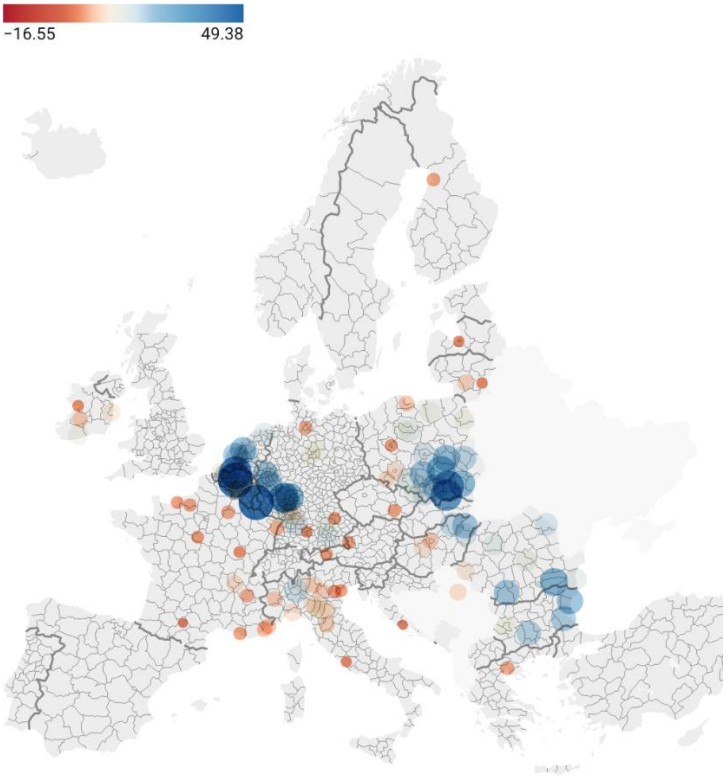


Figure 11 Moran's local index of spatial autocorrelation of labour productivity among the EU metropolitan regions, 2019

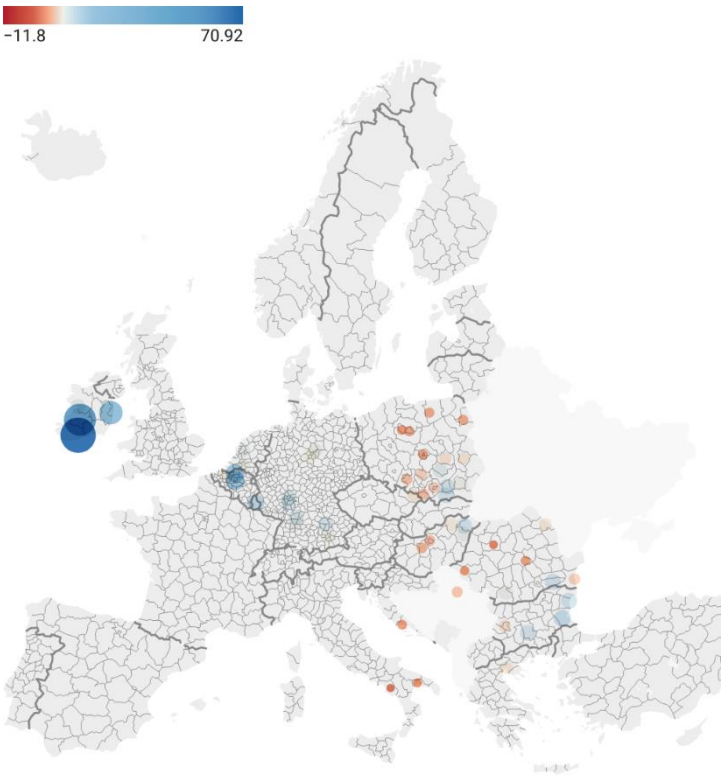
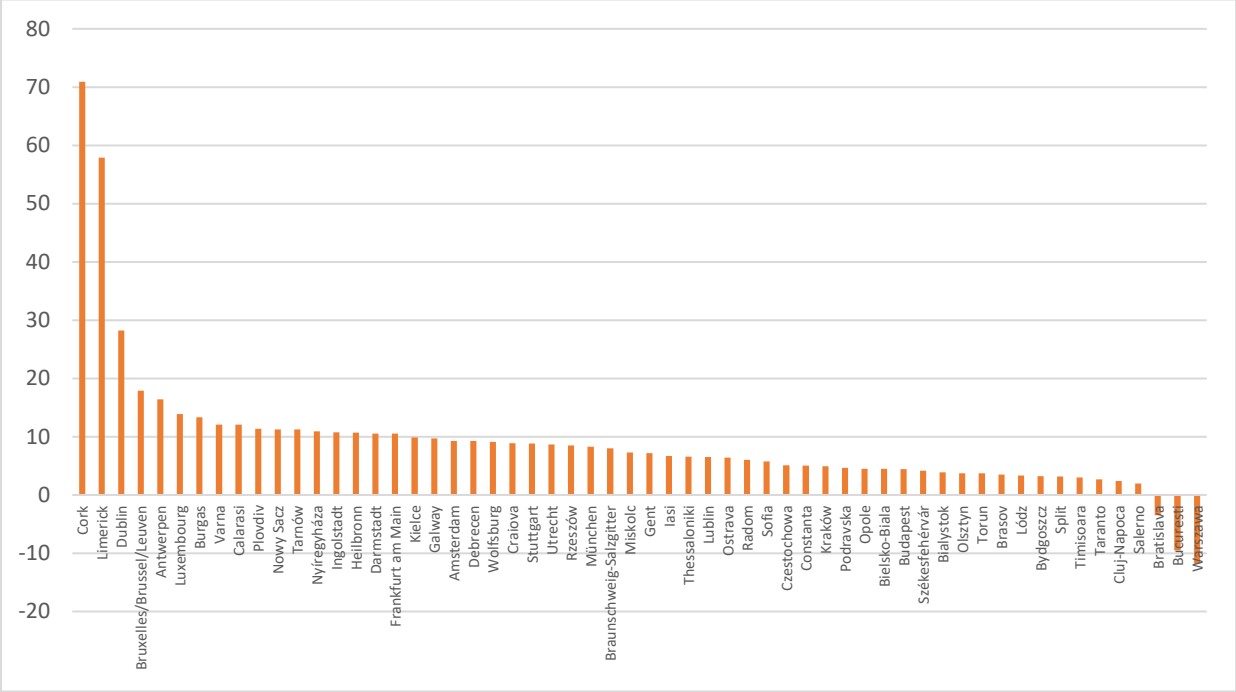
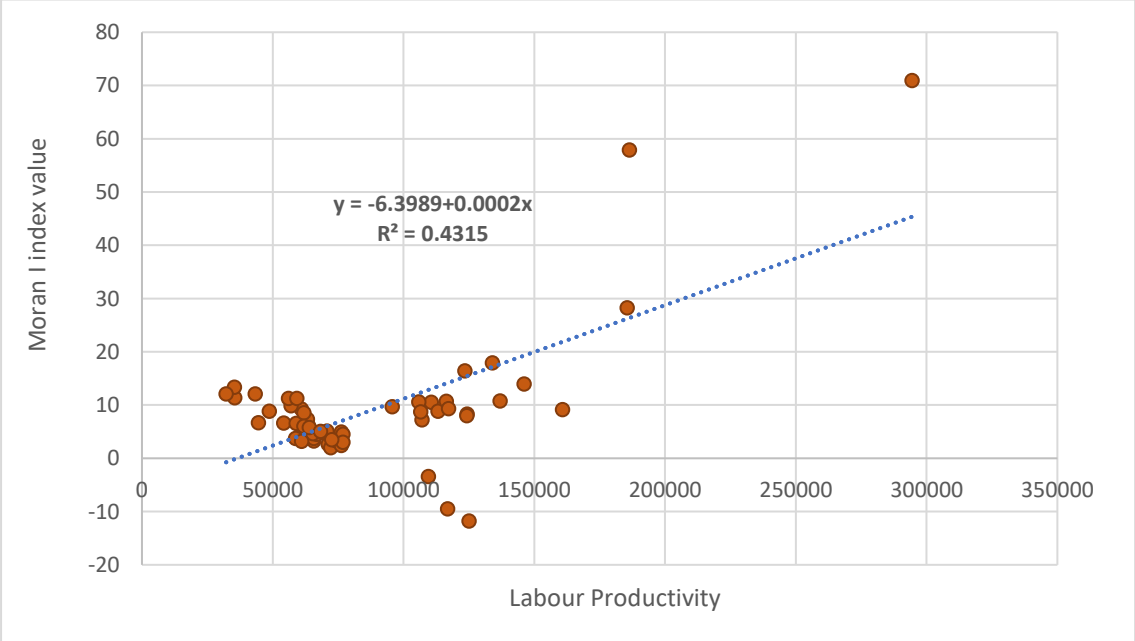


Figure 12 Moran's local index of spatial autocorrelation of labour productivity in the EU metropolitan regions, 2019



Note: Statistically significant Moran's I index values above the 95% level of confidence are recorded.

Figure 13 Relationship between labour productivity and the corresponding Moran's local index of spatial autocorrelation in the EU metropolitan regions, 2019



Note: Statistically significant Moran's I index values above the 95% level of confidence are recorded.

5. Conclusions and policy implications

This article presented an original analysis of the trends in the level and growth of labour productivity and related gaps and clustering patterns for the metropolitan regions (or functional urban areas) across the EU during the decade 2010-2019. Similar to the findings of other studies focusing on the NUTS-2 regions, the empirical results verify the positive effects of size, the considerable and persistent productivity disparities both across and within most of the countries, and the dynamism of eastern European metro areas. By and large, the EU metro areas have not well performed in generating synergetic effects, exhibiting a limited diffusion of high productivity to nearby regions over time. The outcome that many left-behind metro areas have generally continued to be lagging underlines the need to ensure the efficiency while tacking the barriers to spillovers and productivity gains in lagging areas.

The current results also highlight the need to prioritise and integrate decision-making processes to tackle regional productivity shortfalls at various levels of spatial governance, not only focusing on large metropolitan areas, but also on smaller urban regions, to remove development constraints. In particular, the findings underscore an urgent need to shape and/or strengthen place-based policies to address the increased heterogeneity, lack of dynamism, amplified productivity gaps and shortage of synergistic effects, to help all types of metropolitan areas to reach their full potential. These policies may encompass a combination of well-coordinated multi-level spatial strategies, supplementary with the main objectives and priorities of the 2021-2027 EU cohesion policy. They may include the strengthening of metropolitan governance, technological progress, physical and human capital, in conjunction with the efficient land use management, enhancement of agglomeration economies and reinforcement of the intra- and inter-regional market access.

The accessibility enhancement on lagging but dynamic metropolitan regions, possibly together with zoning and land use reforms, would allow more people to affordably access and benefit from working or investing in them. The effective and equitable accessibility to jobs and essential services across metro areas could be arguably fostered by a more balanced spatial development, such as a polycentric type of regional urbanisation (Arbabi et al., 2020). In the latter case, productivity gains could arise from the development sprawl and ability to capitalise on urban-rural linkages and "borrowing" agglomeration effects from nearby cities, in tandem with increased inter-

city connectivity, favourably, by high-quality demand-responsive fixed-route transport systems. However, recent findings suggest that polycentric urban regions are unable to substitute for the economic urbanisation externalities associated with a single large city (Ouwehand et al., 2022), and that, although polycentric development can effectively reduce regional disparities in urban regions, it cannot simultaneously promote productivity (Li et al., 2024).

The catching-up or convergence process and the problem of left-behindness could also be further investigated in specific activities that form major drivers of metropolitan productivity and agglomeration economies, as with respect to technology and innovation gaps, education and skill gaps, and problems related to the speed and fairness of the digital and green transition (Rodríguez-Pose et al., 2024). Especially, the diffusion of productivity from frontier firms, industries and, by extension, their regions to their lagging counterparts could be accelerated through transferring innovative management practices, business processes and new technologies. Specifically with regard to the eastern EU regions, spatial planning institutions should be strengthened, in addition to investing in physical and human capital, and improving regional connectivity with large central EU markets, in order to facilitate the catching-up process, and, at the same time, reduced disparities between the capital regions and peripheral urban areas.

Finally, the consideration of more detailed spatial information originating from the pan-European land cover and land use datasets, such as the CORINE land cover inventory, the Urban Atlas land cover and land use database for large FUAs, and remote sensing imagery from other satellite data (Landsat), could be useful to identify cross-regional and intra-regional changes in metropolitan development. These changes could be expressed through the spatio-temporal evolution of urban sprawl, physical capital stock, employment, income and, hence, labour and other productivity indices, such as total factor productivity (TFP), and associated gaps between and within metro areas, the core and the periphery of them.

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