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Changing spatial patterns of the service industry in Germany: evidence on functional differentiation in the urban system

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Abstract: The service economy is a key driver of regional development, yet little is known about how different service activities contribute to regionalisation processes within large city regions. This paper analyses employment dynamics across Germany's 48 large city regions between 2012 and 2025. Building on the service typology of Glückler and Hammer (2011), occupations are grouped into knowledge-intensive consumer services (KICS), knowledge-intensive business services (KIBS), technology-intensive knowledge-intensive business services (TKIBS), operational consumer services (OCS), and operational business services (OBS). Using employment data from the Federal Employment Agency and principal component analysis, the study examines spatial development patterns and functional dimensions of service-sector growth. The results reveal substantial differences between service categories. While knowledge-intensive business services remain closely associated with metropolitan environments, employment growth increasingly extends into commuter areas beyond urban cores. Moreover, the principal component analysis identifies five functional dimensions that cut across conventional service categories: knowledge-intensive urban services, commercial and business services, care and infrastructure services, urban security and facility services, and finance and insurance services. The findings suggest that contemporary service-sector development is structured less by traditional sectoral classifications than by broader city-regional functional regimes. Understanding metropolitan transformation therefore requires a stronger focus on functional interdependencies across entire city regions.

Keywords: city regions; service economy; regionalisation; principal component analysis; functional specialisation; Germany

1 Introduction

For several decades, economic development in advanced economies has been characterised by the growing importance of service and knowledge-based activities (Bell 1976; Foray and Lundvall 1998; OECD 1996). At the same time, the spatial organisation of these activities has undergone substantial change. While large urban agglomerations continue to play a central role in economic development, many functions are no longer concentrated exclusively in core cities. Instead, numerous studies have documented regionalisation processes in which economic activities increasingly extend into the surrounding areas of large city regions (Feng et al. 2019; Hoyler et al. 2008; Shearmur and Alvergne 2002; Zhang et al. 2018).

Regionalisation processes are commonly understood as the simultaneous concentration of economic activities in large agglomerations and the decentralisation of selected functions towards surrounding municipalities within these agglomerations (Growe and Volgmann 2022). While the existence of such processes is well established (Cardoso and Meijers 2021a, 2021b; Volgmann and Münter 2018), important questions remain regarding their spatial characteristics and underlying economic drivers. In particular, it remains unclear whether different types of service activities exhibit similar regionalisation patterns or whether they follow distinct spatial trajectories within urban regions.

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Existing research has predominantly focused on knowledge-intensive and advanced producer services (Heidinger et al. 2023; Simmie and Strambach 2006), whereas the broader diversity of service activities has received less attention. Yet services differ considerably regarding their knowledge base, technological requirements and demand orientation (Glückler and Hammer 2011, 2013). These differences are likely to influence their locational behaviour and consequently their contribution to regionalisation processes (Wagner and Growe 2023; Zöllner et al. 2023). Understanding the geography of regionalisation therefore requires a differentiated perspective on the service economy rather than focusing on individual service segments alone.

To address this gap, this study analyses the spatial development of different service categories within the German urban system. Following the framework proposed by Glückler and Hammer (2013, 2011), services are differentiated according to demand orientation, knowledge intensity and technology intensity. The analysis focuses on three research questions: 1) How have different service categories developed spatially across Germany's large city regions between 2012 and 2025? 2) What functional patterns of service-sector specialisation emerge across Germany's large city regions, and what do they reveal about contemporary city-regional divisions of labour? 3) To what extent do these empirically observed dimensions correspond to the service typology proposed by Glückler and Hammer (2011, 2013)?

Empirically, the study examines changes in employment structures within Germany's large city regions and their surrounding municipalities. To capture the spatial extent of regionalisation processes, surrounding areas are differentiated into several distance-based rings around large core cities. This approach allows for a systematic comparison of regionalisation dynamics across different segments of the service economy.

The paper contributes to the literature on service-sector geographies and city-regional development in three ways. First, it provides a differentiated analysis of employment dynamics across major service categories in Germany's large city regions. Second, it identifies empirically emerging functional dimensions of service-sector development using principal component analysis. Third, it evaluates whether established service typologies adequately capture contemporary patterns of city-regional specialisation and regionalisation. In doing so, the paper advances current debates on metropolitan restructuring by highlighting the functional interdependencies between urban cores and their surrounding areas.

2 Spatial dynamics of regionalisation processes

A rough distinction is made between processes of more area-wide regionalisation in the sense of regional sprawl understood as 'land-change processes' (Pagliarin and de Decker 2021, 2) or regional (sub)urbanisation (Soja 2013) understood as 'planned spatial phenomenon' (Pagliarin and de Decker 2021, 2) and more centre-focused regionalisation in the sense of the formation and strengthening of new centres in the surrounding urban-regional area (Krehl 2018; Shearmur and Alvergne 2002; Terfrüchte and Growe 2024; Volgmann and Münter 2018).

The first perspective corresponds to overcoming urban-rural and therefore -regional dichotomies, assuming that regionalisation leads to the development of peri-urban structures (Shaw et al. 2020; Urso 2021; Vidovich and Scolari 2022). Consequently, the sharp phenomenological distinction between 'urban' and 'rural' is increasingly blurred (Lichter et al. 2021), replaced by a patchwork of traditional and new centralities. However, rural areas in urban regions are not rural-peripheral areas, being already comparatively well connected to major centres in the broader surrounding area (urban-regional linkages). Commuter links render a dynamic of exchange with the large centres (Hipp et al. 2022), meaning 'urban hierarchies and core-regional relations are becoming more diverse' (Humer et al. 2022, 21). Regionalisation processes are therefore increasingly shaped by accessibility conditions, labour-market interactions and the functional integration of cities and their surrounding areas (Wenner et al. 2020).

The second perspective views regionalisation as the formation of polycentric structures in metropolitan areas, linking development to existing and emerging centres (Cardoso and Meijers 2021b; Growe and Volgmann 2022; Halleux et al. 2021). This process creates dense agglomerations, upgrading surrounding areas (Cardoso and Meijers 2021a). Large cities serve as anchor points for socio-economic growth, while smaller and medium-sized towns in the surrounding area as well as new centres – such as edge cities (Garreau 1992) or infrastructure hubs (airports, train stations) – contribute to polycentric regional development (Kane et al. 2018; Krehl 2018; Wagner and Growe 2022; Terfrüchte and Growe 2024; Wenner et al. 2020).

Regarding the spatial scope of regionalisation processes, two effects are described in the literature (Volgmann et al. 2022):

– Spillover effects occur in the immediate surroundings of large cities, driven by rising costs in core urban areas (Münter and Osterhage 2018). These effects resemble

suburbanisation but require a booming core city, pushing development into neighbouring municipalities (Volgmann et al. 2022). Infrastructure projects often amplify this process by accommodating urban expansion (Wenner et al. 2020).

– Enrichment effects extend further into the urban region, adding new functions beyond the core's influence (Volgmann et al. 2022). Unlike spillover effects, they integrate polycentric development patterns (Lichter et al. 2021) and foster functional enrichment, reducing strong differences between urban centres and rural surroundings (Urso 2021). Soja (2013) distinguishes these developments from mere suburban dormitory towns, highlighting their role in shaping dynamic urban regions.

3 Service economies in city regions

The transition from an industrial economy towards a service and knowledge economy has been one of the most significant socio-economic transformation of recent decades (Bell 1976; Foray and Lundvall 1998; OECD 1996). As economic activities have become increasingly knowledge-based and specialised, services have assumed a central role in coordinating production processes, facilitating innovation and supporting economic development (Cook et al. 1999; Taylor et al. 2013). Consequently, the service economy has become a key component of urban and regional development and an important driver of contemporary regionalisation processes.

From a spatial perspective, the rise of the service and knowledge economy has long been associated with the advantages of large urban agglomerations. Agglomeration economies provide access to specialised labour markets, large consumer and business markets, and opportunities for interaction and learning (Lichter et al. 2021; Wagner and Growe 2023). At the same time, research increasingly emphasises that economic development is not solely determined by geographical concentration but also by the relations connecting places (Heidinger et al. 2023; Zöllner et al. 2023). While classical approaches focused on hierarchical systems of centres, more recent perspectives stress the role of flows of information, knowledge, people and business interactions. Central Flow Theory conceptualises cities as nodes within networks of economic relations rather than merely as locations within a settlement hierarchy (Taylor et al. 2010). Similarly, studies on polycentric metropolitan development and the German knowledge economy demonstrate that economic activities are increasingly organised through networks that combine local embeddedness with supra-local connectivity (Hall and Pain 2006; Hoyler et al. 2008; Lüthi et al. 2011). Consequently, regionalisation processes can be understood as the outcome of both agglomeration economies and the growing functional integration of cities and their surrounding areas. While the present study does not analyse such networks directly, these perspectives provide an important theoretical framework for understanding why service activities may increasingly extend beyond traditional urban cores.

Capturing these processes requires moving beyond a uniform understanding of services. Services differ considerably regarding their knowledge base, client orientation and technological requirements, resulting in distinct locational preferences and spatial development patterns. To account for this heterogeneity, this study adopts the German service economy framework proposed by Glückler and Hammer (2011, 2013), which differentiates services according to demand orientation, knowledge intensity and technology intensity.

Based on these dimensions, five service categories are distinguished: consumer-related knowledge-intensive services (KICS), business-oriented knowledge-intensive services (KIBS), technology- and knowledge-intensive business services (TKIBS), consumer-related operational services (OCS), and business-oriented operational services (OBS). These categories differ fundamentally in their spatial requirements. TKIBS und KIBS are expected to benefit most strongly from agglomeration economies because they depend on highly qualified labour, specialised knowledge and frequent interaction with clients and partners. KICS, including health and educational services, are also knowledge-intensive but are more strongly influenced by population distribution and the provision of public services. In contrast, operational services are less dependent on knowledge exchange. OCS primarily follow local demand and everyday consumption patterns, whereas OBS are linked to the functional organisation of regional economies and the spatial division of labour between firms and institutions. As a result, different service categories are likely to exhibit distinct regionalisation dynamics and varying degrees of concentration in urban cores, secondary centres and surrounding areas. Analysing these categories separately therefore provides a more comprehensive perspective on how different segments of the service and knowledge economy contribute to the evolving spatial structure of German city regions.

Recent evidence supports such differentiated perspectives. Knowledge-intensive firms tend to concentrate in locations characterised by accessibility, agglomeration advantages and dense economic environments (Heidinger et al.

2023), while analyses of advanced producer services reveal differentiated and evolving centre-periphery structures across Germany (Zöllner et al. 2023). These findings suggest that regionalisation processes cannot be understood through a single service category alone but require consideration of the diverse spatial logics that characterise different segments of the service economy.

4 Study area, data and methods

The following section describes Germany's large city regions as the study area (Section 4.1). Then, the exact structure of the data available for analysis in the period 2012 to 2025 is presented (Section 4.2). Finally, the methodological approach of the Principal Component Analysis (PCA) is explained (Section 4.3).

4.1 Study area

The study area comprises Germany's 48 large city regions, which were redefined in 2024. The regions around large cities are defined as those municipalities and associations of municipalities whose main commuter relationships lead to the respective large city and, thus, the centre of the large city region. Commuter movements are measured based on everyday flows between the place of residence and place of work of employees subject to social insurance contributions.

Large city regions consist of four distinct areas (Federal Institute for Research on Building, Urban Affairs and Spatial Development n.d.):

- 'centres', which are large cities with more than 100,000 inhabitants and a commuter surplus,
- 'supplementary areas' adjacent to the centre (with a high daily population density, a commuter surplus or more than 50 % commuting to the centre)
- 'narrower commuter areas' have 50 % commuting to the core,
- 'wider commuter areas' have a 25–50 % commuting rate.

While the use of predefined spatial units inevitably influences empirical results, the delineate of the Federal Institute for Research and Building, Urban Affairs and Spatial Development provides a functionally grounded representation of city regional labour-market relationships based on commuting flows. It therefore offers a suitable framework for analysing service-sector regionalisation, even though alternative regional delineates may produce somewhat different spatial patterns.

Not all large city regions include a supplementary area. The large city regions of Münster, Trier, Kaiserslautern, Erfurt, Jena, Halle, Göttingen, Paderborn, Magdeburg, Bremen, Oldenburg, and Bremerhaven do not contain such an area. Overall, the large city regions considered in this study (as of 2024) account for approximately 70 % of Germany's population while covering around 40 % of the country's total land area (Federal Institute for Research on Building, Urban Affairs and Spatial Development n.d.).

4.2 Data

The analysis is conducted based on employees by occupation, according to the classification of occupations (Federal Employment Agency 2021 – KldB 2010), and not based on employees by economic sector (Federal Employment Agency 2008 – WZ 2008), as in Glückler and Hammer (2013). For this purpose, we have assigned the individual sectors from the categorisation by economic sector (Federal Employment Agency 2008 – WZ 2008) to the individual occupation groups (Federal Employment Agency 2021 – KldB 2010) as precisely as possible (see Table 1). The use of occupations directly reflects the skills and knowledge of the workforce, therefore better reflecting the functional structure of a region than economic sectors. Occupations are also a good indicator of human capital and, thus, the innovative capacity of a region. A further advantage of an analysis based on employees by occupation is the possibility of functionally analysing places of work in small spatial units, such as municipal associations. The data cover all employees subject to social insurance contributions and represent about 75 % of the total labour force. Employees are distinguished by occupation (i.e., employees subject to social security contributions by occupation). This classification is based on the grouping of similar occupations and not on the qualification of the person or the classification of the employer by economic activity, enabling the analysis of functional patterns.

The breakdown of occupations into five different types of service sectors appears in Table 1. In 2025, Germany recorded a total of 34,884,438 million employees subject to social insurance contribution. Among these, knowledge-intensive service sectors accounted for a substantial share of employment. Knowledge-intensive consumer-related services (KICS) employed 1,447,204 people, representing 4.3 % of all socially insured employees. Knowledge-intensive business services (KIBS) constituted a much larger segment, with 4,719,553 employees (13.5 %). Within this group, technology-intensive knowledge-intensive business services (TKIBS) accounted for 4,358,917 employees, corresponding to 12.5 % of all employees subject to social insurance contribution.

Table 1: Breakdown of service occupations. Own illustration.

Service category		Occupation groups	Classification of occupations (2010)
Knowledge-intensive	Consumer-related and not business-related (KICS)	Health	624, 814, 815, 816, 818
		Teaching	841, 842, 843, 844, 845
	Business-oriented (KIBS)	Media, design and public relations	232, 233, 234, 921, 922, 923, 924, 931
		Corporate management	711, 712, 713
		Creative-cultural and entertainment services	933, 934, 935, 936, 94
		Finance and insurance	721
		Law and economics	722, 723, 731
		Real estate industry	613
Technology-intensive	Knowledge-intensive and business-oriented (TKIBS)	Science – natural science	411, 412, 413, 414, 421
		Science – social science	911, 912, 913, 914
		Technical services	252, 261, 262, 263, 271, 812
		Civil engineering	272, 311, 312, 422, 423, 932
		Information technology services	431, 432, 433, 434
Operational	Consumer-related and not business-related (OCS)	Building services	331, 332, 333, 342, 343, 541, 832
		Social services	811, 813, 817, 82, 833
		Retail and wholesale trade	611, 612, 621, 622, 623, 625
		Tourism, accommodation, gastronomy, leisure	63
	Business-oriented (OBS)	Administration	341, 513, 714, 715, 732, 733
		(Public) security	512, 515, 53
		Transportation (incl. maintenance activities)	511, 514, 516, 521, 522, 523, 524, 525

More broadly, operational consumer-related services (OCS) represented the largest category, employing 10,053,644 people (28.8 %), while operational business-related services (OBS) accounted for 7,584,450 employees (21.7 %). These figures highlight the significant role of knowledge-intensive and service-oriented activities within Germany's employment structure, underlining their importance for contemporary economic development and regional transformation processes.

4.3 Methods: principal component analysis

To reduce the dimensionality of the dataset and to identify the dominant patterns of variability among the observed variables, Principal Component Analysis (PCA) was applied. The PCA approach is a widely applied multivariate statistical method for the exploration and reduction of high-dimensional datasets in geographical research (Demsar et al. 2013). Through the reduction of data complexity while retaining the majority of the original information, PCA enables the identification of key dimensions underlying the spatial structure of the study area and provides a robust basis for subsequent statistical investigations. The correlation matrix (see Table 2) indicates significant associations among the selected variables, pointing to latent structures in the data that can be effectively identified through the PCA.

The technique transforms a set of potentially correlated variables – as in our case the different occupation groups – into a new set of orthogonal (uncorrelated) variables. These components are derived as linear combinations of the original variables and are ordered accordingly to the proportion of total variance explained (see Table 3). Consequently, the first principal component captures the largest amount of variance in the dataset, while each subsequent component explains the maximum remaining variance under the constraint of orthogonality.

Component retention was based on the Kaiser criterion (eigenvalues > 1) and supported by visual inspection of the scree plot (Backhaus et al. 2018, 448f.). To facilitate interpretation, a varimax rotation was applied, maximising the variance of component loadings and thereby enhancing the distinction between variables associated with different

Table 2: Correlation matrix of service occupation indicators. Own illustration.

	Health	Teaching	Media, design and public relations	Corporate Management	Creative-cultural and entertainment services	Finance and insurance	Law and economics	Real estate industry	Science – natural science	Science – social science	Technical services	Civil engineering	Information technology services	Building services	Scoial services	Retail and wholsale trade	Tourism, accommodation, gastronomy, leisure	Administration	(Public) security	Transportation (incl. maintenance activities)
Health		0.278**	0.265**	0.413**	0.262**	0.251**	0.386**	0.148*	0.117	-0.118	0.042	0.281**	-0.057	0.173*	0.464**	0.252**	0.358**	0.006	-0.153*	0.309*
Teaching	0.287**		0.756**	0.650**	0.687**	0.254**	0.663**	-0.225**	0.203**	-0.456**	0.249**	0.702**	0.660**	0.304**	0.374**	0.519**	0.675**	0.641**	-0.102	0.355**
Media, design and public relations	0.265**	0.756**		0.852**	0.721**	0.304**	0.841**	-0.382**	0.187*	-0.455**	0.349**	0.786**	0.810**	0.209**	0.454**	0.667**	0.646**	0.621**	-0.139	-0.380**
Corporate Management	0.413**	0.650**	0.852**		0.699**	0.402**	0.879**	-0.289**	0.284**	-0.335**	0.532**	0.748**	0.741**	0.163*	0.416**	0.713**	0.541**	0.442**	-0.172*	0.342**
Creative-cultural and entertainment services	0.262**	0.687**	0.721**	0.699**		0.153*	0.744**	-0.197**	0.268**	-0.321**	0.423**	0.562**	0.682**	0.334**	0.454**	0.707**	0.622**	0.592**	-0.212**	0.478**
Finance and insurance	0.251**	0.254**	0.304**	0.402**	0.153*		0.425**	-0.148*	0.053	-0.257**	0.163*	0.509**	0.241**	0.031	0.307**	0.248**	0.087	-0.069	0.0105	0.196**
Law and economics	0.386**	0.663**	0.841**	0.879**	0.744**	0.425**		-0.124	0.204**	-0.476**	0.530**	0.687**	0.764**	0.187*	0.409**	0.804**	0.615**	0.421**	-0.145	
Real estate industry	0.148*	-0.225**	-0.382**	-0.289**	-0.197**	-0.148*	-0.124		-0.055	0.342**	-0.137	-0.379**	-0.466**	-0.288**	0.058	0.023	-0.173*	-0.252**	0.030	0.051
Science – natural science	0.117	0.203**	0.187*	0.284**	0.268**	0.053	0.204**	-0.055		-0.039	0.176*	0.068	0.200**	0.029	0.111	0.244**	0.200**	0.215**	-0.051	0.187*
Science – social science	-0.188	-0.456**	-0.455**	-0.335**	-0.321**	-0.257**	-0.476**	0.342**	-0.039		-0.151*	-0.395**	-0.494**	-0.042	-0.159*	-0.271**	-0.498**	-0.290**	0.188	-0.268**
Technical services	0.042	0.249**	0.349**	0.532**	0.423**	0.163*	0.530**	-0.137	0.176*	-0.151*		0.343**	0.499**	0.188*	0.061	0.545**	0.260**	0.257**	0.071	0.106
Civil engineering	0.281**	0.702**	0.768**	0.748**	0.562**	0.509**	0.687**	-0.379**	0.068	-0.395**	0.343**		0.667**	0.188*	0.402**	0.502**	0.529**	0.519**	-0.050	0.344**
Information technology services	-0.057	0.660**	0.810**	0.741**	0.682**	0.241**	0.764**	-0.466**	0.200**	-0.494**	0.499**	0.667**		0.139	0.144	0.625**	0.549**	0.615**	-0.142	0.194**
Building services	0.173*	0.304**	0.209**	0.163*	0.334**	0.031	0.187*	-0.228**	0.029	-0.042	0.188*	0.188*	0.139		0.081	0.316**	0.126	0.327**	0.337**	0.358**
Social services	0.464**	0.374**	0.454**	0.416**	0.454**	0.307**	0.409**	0.058	0.111	-0.159*	0.061	0.402**	0.144	0.081		0.278**	0.353**	0.277**	-0.243**	0.516**
Retail and wholsale trade	0.252**	0.519**	0.667**	0.713**	0.707**	0.248**	0.804**	0.023	0.244**	-0.271**	0.545**	0.504**	0.625**	0.316**	0.278**		0.398**	0.511**	0.073	0.495**
Tourism, accommodation, gastronomy, leisure	0.358**	0.675**	0.646**	0.541**	0.622**	0.087	0.615**	-0.173*	0.200**	-0.498**	0.260**	0.529**	0.549**	0.126	0.353**	0.398**		0.550**	-0.219**	0.241**
Administration	0.006	0.641**	0.621**	0.442**	0.592**	-0.069	0.421**	-0.252**	0.215**	-0.290**	0.257**	0.519**	0.615**	0.327**	0.277**	0.511**	0.550**		0.039	0.429**
(Public) security	-0.153*	-0.102	-0.139	-0.172*	-0.212**	0.105	-0.145	0.030	-0.051	0.118	0.071	-0.051	-0.142	0.337**	-0.243**	0.073	-0.291**	0.039		0.125
Transportation (incl. maintenance activities)	0.309**	0.355**	0.380**	0.342**	0.478**	0.196**	0.368**	0.051	0.187*	-0.268**	0.106	0.344**	0.194**	0.358**	0.516**	0.495**	0.241**	0.429**	0.125	

**Significant correlation at 0.01 level (2-sided). *Significant correlation at 0.05 level (2-sided).

components. The interpretation of the extracted components was based on the magnitude and direction of variable loadings. Variables with loadings greater than |0.5| were considered to have a meaningful contribution to the corresponding component, although the threshold was adapted where necessary to improve interpretability (Backhaus et al. 2018, 451).

5 Empirical results and analysis

The PCA principally aims to provide the dominant patterns of variability among the used employee dataset. Furthermore, we aim to examine the extent to which the theoretical classification of different employee groups into service categories – KICS, KIBS, TKIBS, OCS, and OBS – is reflected in the employment structures of German large city regions. In Section 5.1, we examine the results of the PCA in detail and discuss the underlying patterns of variation in the employment data. We then provide analytical explanations for the extent to which the empirical employment structures correspond to the theoretical classification of employee groups into the different service categories.

5.1 Development of the service sectors in urban-regional integration regions

Between 2012 and 2025, employment growth varied considerably across Germany's service sectors. The strongest increase was recorded in knowledge-intensive consumer-related services (KICS) (+37.4 %), followed by technology-intensive knowledge-intensive business services (TKIBS) (+28.1 %). Employment also grew substantially in operational consumer-related services (OCS) (+22.1 %) and

Table 3: Principal components of occupation groups in the different commuter areas in Germany's large city regions. Own illustration.

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	8.356	41.779	41.779	8.356	41.776	41.776	4.876	24.380	24.380
2	1.858	9.290	51.096	1.858	9.290	51.0569	3.777	18.886	43.266
3	1.658	8.290	59.359	1.658	8.290	59.359	2.752	13.762	57.029
4	1.369	6.847	65.206	1.369	6.847	66.206	1.703	8.531	65.542
5	1.283	6.417	72.623	1.283	6.417	72.623	1.416	7.081	72.623
6	0.907	4.537	77.160						
7	0.819	4.093	81.253						
8	0.766	3.832	85.085						
9	0.658	3.291	88.376						
10	0.491	2.454	90.830						
11	0.416	2.082	92.912						
12	0.313	1.563	94.475						
13	0.257	1.286	95.761						
14	0.225	1.126	96.886						
15	0.187	0.934	97.820						
16	0.144	0.722	98.542						
17	0.110	0.550	99.092						
18	0.078	0.389	99.482						
19	0.065	0.326	99.807						
20	0.039	0.193	100.000						

operational business-related services (OBS) (+20.4 %), while knowledge-intensive business services (KIBS) experienced a more moderate increase of 15.9 %. These developments reflect the broader shift towards a knowledge-based economy and the growing importance of innovation, digitalisation, and specialised services in advanced economies (Shearmur and Doloreux 2015; Strambach 2008). In particular the strong expansion of KICS and TKIBS highlights the increasing relevance of knowledge-intensive and technology-oriented activities as drivers of regional economic development and structural transformation (Asheim and Gertler 2005; Martin and Sunley 2006).

A geographic analysis reveals distinct spatial patterns. Glückler and Hammer (2013) found KIBS concentrated in urban centres, while OBS and TKIBS showed diffusion patterns. OBS spread across regions, while OCS and KICS became more spatially concentrated in certain areas.

Figure 1 illustrates above-average growth in service sectors across Germany's large city regions (2012–2025), with central and eastern cities experiencing strong core-centred growth, and southern regions also showing high service sector expansion.

The spatial patterns of above-average employment growth broadly confirm the theoretical expectations derived from the differentiated service categories (chapter 3). Three main patterns can be identified:

- KICS: The comparatively dispersed patterns of KICS growth is consistent with theoretical expectations. Since many activities in this category are linked to healthcare and education, their development depends not only on knowledge intensity but also on population distribution, accessibility, and public service provision. Therefore, above-average growth is found across centres, but also in the narrower and wider commuter areas, especially in southern Germany.
- KIBS and TKIBS: As expected, KIBS and TKIBS exhibit the strongest concentration in economically dynamic large city regions. Their dependence on highly skilled labour, specialised knowledge, and intensive interaction with clients and partners is reflected in pronounced growth within large city regions. However, many of the most dynamics locations are situated in the narrower and wider commuter belts rather than in the core cities themselves. This suggests that agglomeration economies are increasingly regionalised, allowing firms to benefit from metropolitan resources while locating in the hinterland of the centres that offers lower costs and greater locational flexibility.
- OCS and OBS: Operational services display the broadest geographical spread. While OBS growth reflects the functional organisation of regional economies and inter-firm divisions of labour, OCS are primarily shaped by local demand and everyday consumption

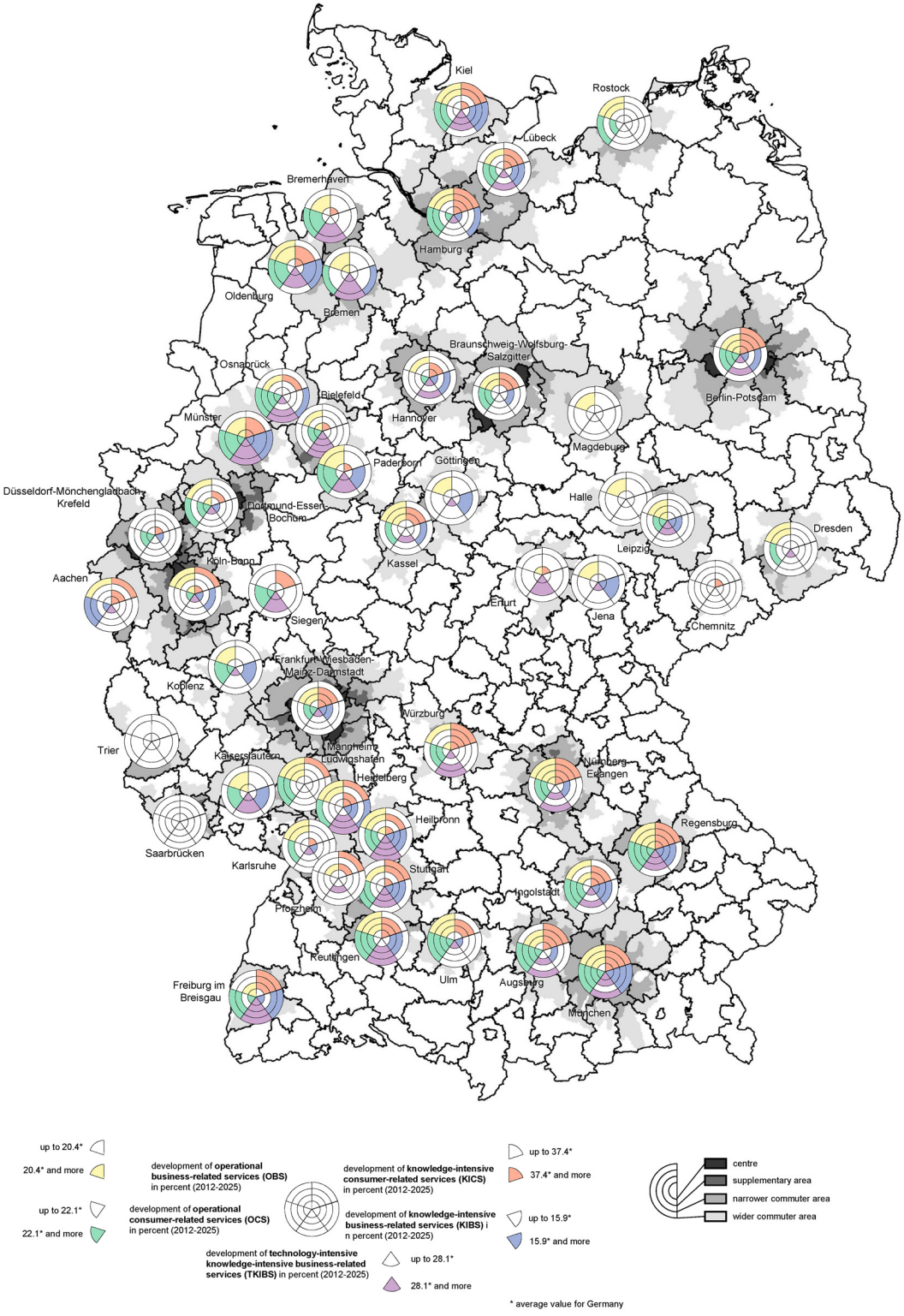

Figure 1: Development of the service sectors in the large city regions in Germany (2012–2025). Own illustration.

patterns. Consequently, above-average employment growth occurs across a wide range of centres and commuter areas, indicating a substantially weaker dependence on agglomeration-based knowledge exchanges than observed for KIBS and TKIBS.

Overall, the results suggest that the degree of spatial concentration decreases from TKIBS and KIBS to KICS, OBS, and OCS. While knowledge-intensive business services remain most closely linked to metropolitan agglomerations, consumer-oriented and operational services increasingly exhibit growth in the hinterland regions, underscoring the importance of functional urban regions as the primary spatial framework of contemporary service-sector development.

5.2 Identifying functional service dimensions: results of the principal component analysis

The principal component analysis was applied to all commuter areas ($n = 178$) of the 48 large city regions in Germany, based on percentage-point changes in 20 occupation groups over the period from 2012 to 2025. The suitability of the data for factor analysis was confirmed by a Kaiser-Meyer-Olkin value of 0.819 (meritorious), which exceeds the minimum recommended level of 0.5 (Backhaus et al. 2018, 423). Component extraction followed the Kaiser-Guttman rule, resulting in five retained components with eigenvalues above one. These components each explain a larger share of variance than a single observed variable and can therefore be regarded as substantively meaningful (Backhaus et al. 2018, 439). Together, the five components explain 72.6 % of the overall variance, as shown in Table 3.

To facilitate the interpretation of the extracted principal components, variables with substantial loadings on the same factor were grouped under a common descriptive level. Assigning such labels is not always straightforward, as a single component may capture several conceptually distinct indicators. In line with established practice, factor loadings of |0.5| or higher/lower were considered indicative of a strong association with a component (Backhaus et al. 2018, 451). To enhance the interpretability of the factor structure, a Varimax rotation was applied, thereby maximising the variance of loadings within each component and producing a clearer separation of variables across factors (see Figures 2, 3, 4, 5, and 6). As an orthogonal rotation technique, Varimax preserves the interdependence of the extracted factors by maintaining zero correlations between them after rotation (Backhaus et al. 2018, 451).

Five principal components can be distinguished: (1) *knowledge-intensive urban services with a strong emphasis on creative and administrative functions*, (2) *commercial and business services*, (3) *care and infrastructure services*, (4) *urban security and facility services* and (5) *finance and insurance services*.

5.2.1 Principal component 1 – knowledge-intensive urban services with a strong emphasis on creative and administrative functions

The first principal component captures a distinct concentration of knowledge-intensive urban services, particularly those related to creative, administrative, and managerial functions (see Figure 2). The occupational groups loading strongly on this component comprise information technology services, media, design and public relations, teaching, civil engineering, tourism and leisure activities, public administration, corporate management, and creative-cultural activities. These sectors share a reliance on highly qualified labour, intensive knowledge exchange, and dense institutional environments, all of which are typically associated with agglomeration economies and large, diversified urban labour markets (Thomas et al. 2022).

In spatial terms, the component exhibits a clear centre-focused bias. The highest scores are observed in Germany's largest large city regions, including Berlin-Potsdam, Hamburg, Munich, Düsseldorf-Mönchengladbach-Krefeld, Mannheim-Ludwigshafen and Heidelberg. This pattern underscores the continued importance of major urban centres as focal points of advanced service functions, reflecting their roles as national hubs for economic coordination, political administration, cultural production, and knowledge generation. Recent empirical research on German large city regions confirms that high-order knowledge functions remain strongly concentrated in core cities despite ongoing suburbanisation and regional redistribution processes (Li et al. 2024).

At the same time, the spatial distribution is not exclusively concentrated in the largest cities but also reveals (weak) processes of regionalisation. Elevated scores are also found in several commuter areas of large city regions like for example Karlsruhe, Ulm, Saarbrücken, Jena, Lübeck, Aachen, Magdeburg, Dortmund-Essen-Bochum and Oldenburg. This indicates that knowledge-intensive urban services are increasingly embedded within a broader and more polycentric urban system, in which regional growth poles complement rather than merely replicate metropolitan functions (Volgmann et al. 2022) and that urban regions are increasingly organised through functional

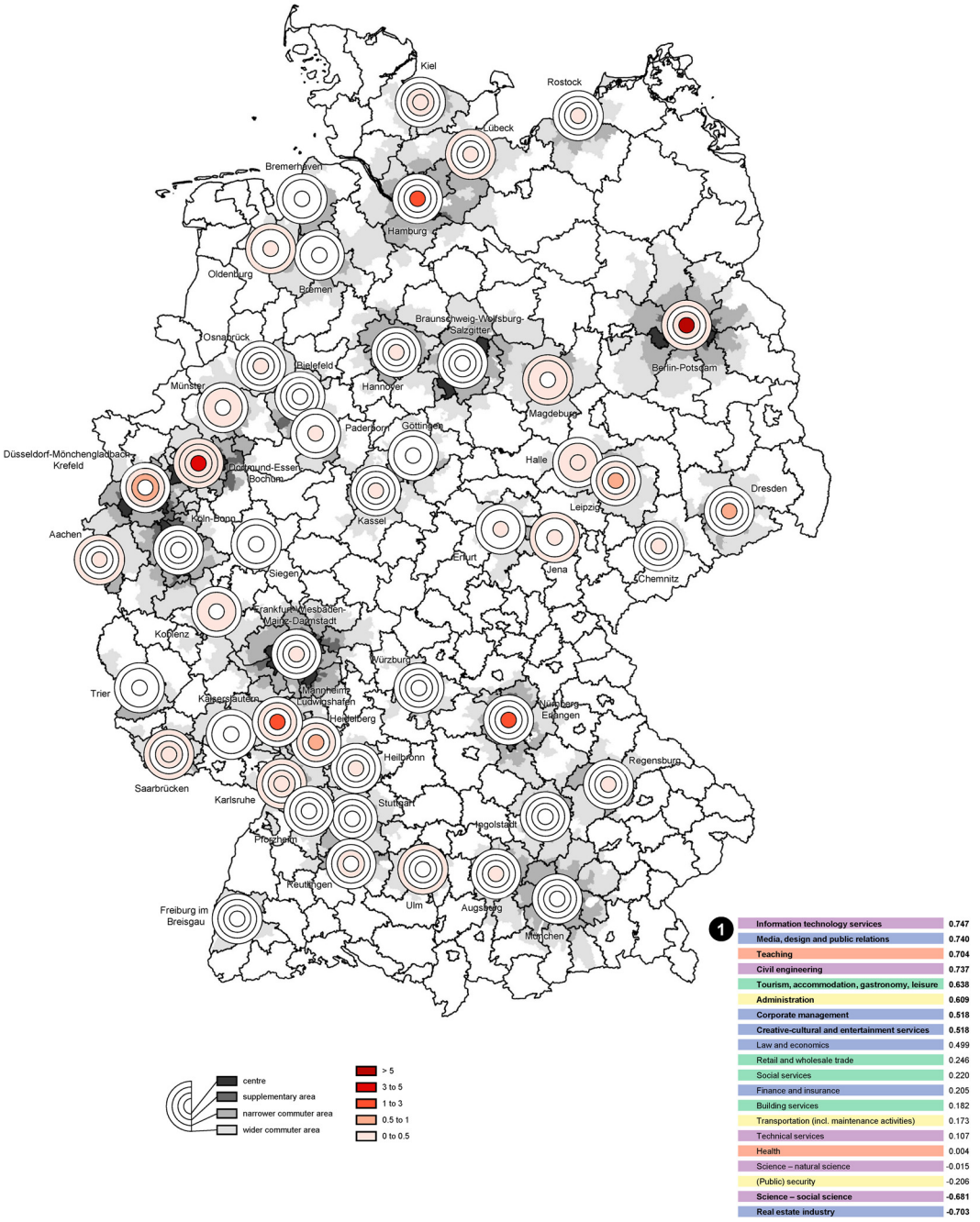

Figure 2: Principal component 1 – knowledge-intensive urban services with a strong emphasis on creative and administrative functions. Own illustration.

networks of secondary cities (Li et al. 2024; Thomas et al. 2022).

Overall, the first principal component can be interpreted as a dimension of knowledge-intensive urban services within large city regions. High-scoring regions are characterised by the joint growth of information technology services, creative and cultural industries, administration, education, engineering, and management functions across both urban centres and their commuter areas. Rather than representing a single service category, the component captures a broader city-regional ecosystem in which knowledge creation, governance, creativity, and organisational functions increasingly co-evolve (Tödtling and Trippl 2021). The observed spatial pattern suggests that agglomeration economies and knowledge networks increasingly operate at the scale of the large city region rather than the core city

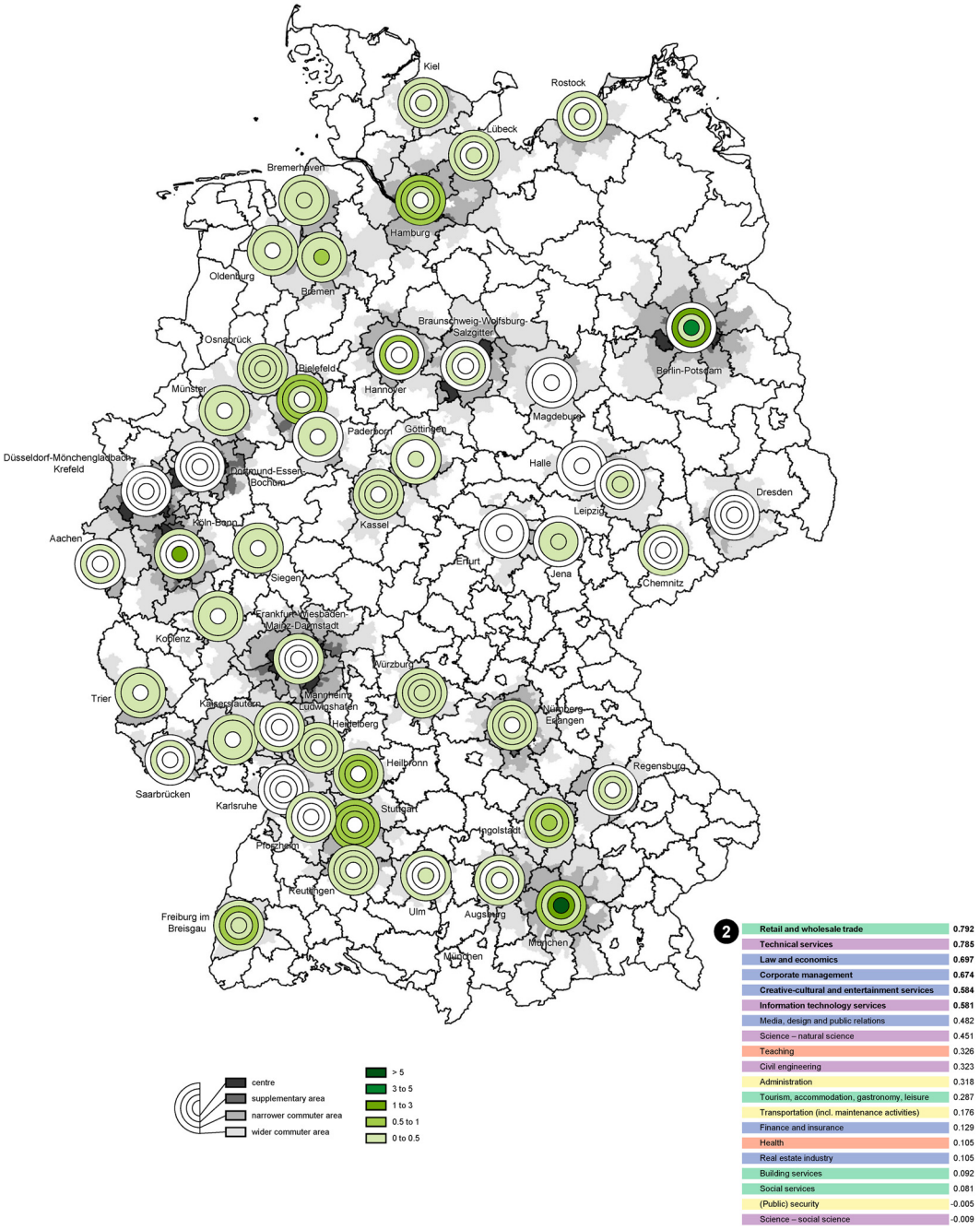

Figure 3: Principal component 2 – commercial and business services. Own illustration.

alone. In this sense, the component reflects the emergence of functionally integrated large city regions in which specialised urban functions extend beyond city centres while remaining anchored in diversified labour markets and institutional environments (Cardoso and Meijers 2021a, 2021b; Growe and Volgmann 2022).

5.2.2 Principal component 2 – commercial and business services

The second principal component captures a distinct pattern of regionalisation in employment change between 2012 and 2025 (see Figure 3). High positive loadings

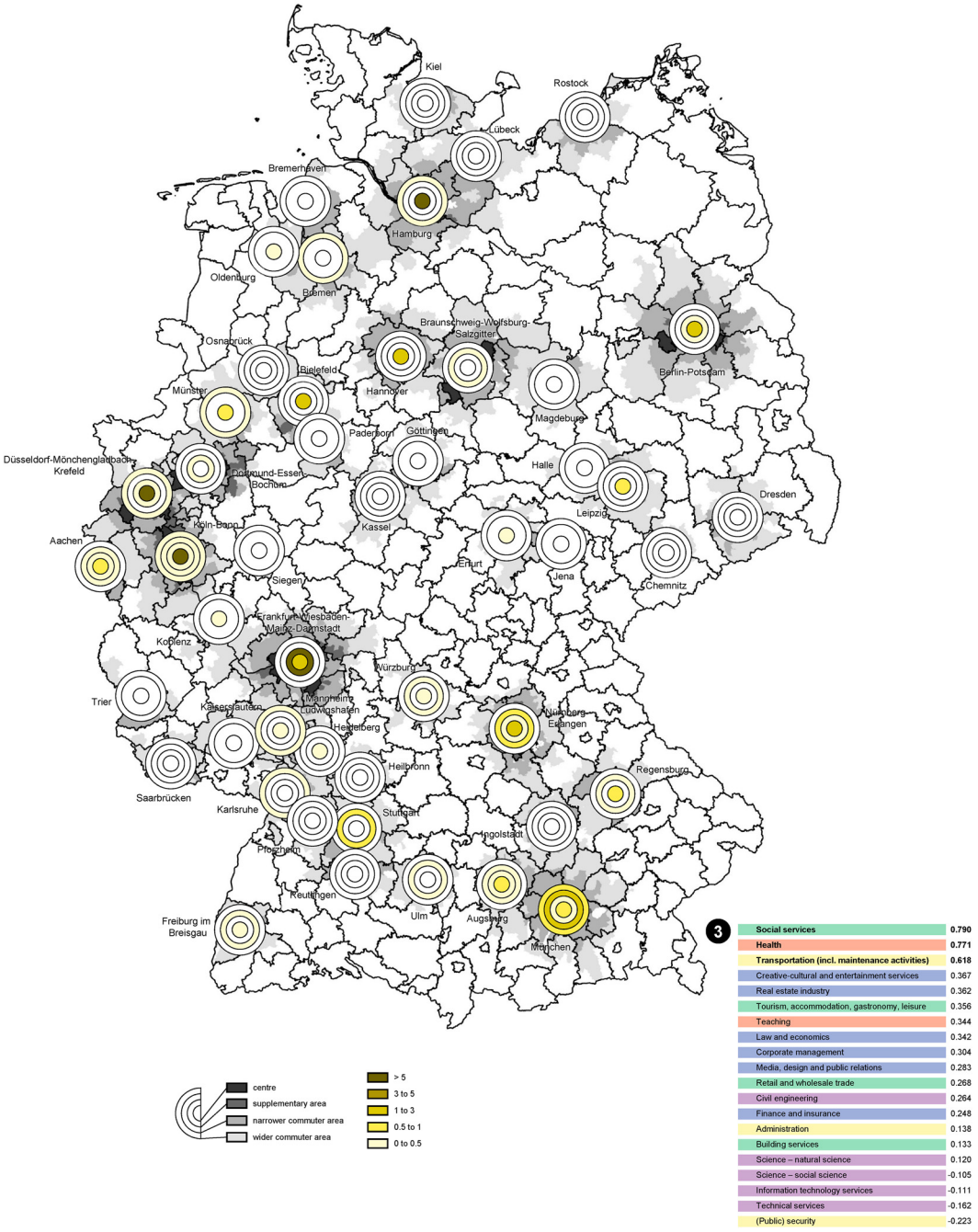

Figure 4: Principal component 3 – care and infrastructural services. Own illustration.

are limited to retail and wholesale trade, technical services, law and economics, corporate management, creative-cultural and entertainment services, and information technology services. These occupations represent a combination of producer services, management functions, knowledge-intensive business services, creative industries, and higher-order commercial activities that are typically concentrated in metropolitan economies (de Ávila Serrano 2019).

The spatial distribution of factor scores reveals a pronounced regionalisation pattern. Positive scores are particularly evident in the commuter areas of several major large city regions, including Hamburg, Berlin-Potsdam, Bremen, Hanover, Ingolstadt, Stuttgart, Heilbronn, Munich, and Freiburg. In the context of the study, positive scores indicate that employment growth in the highly loading occupational groups has increasingly spread throughout the wider

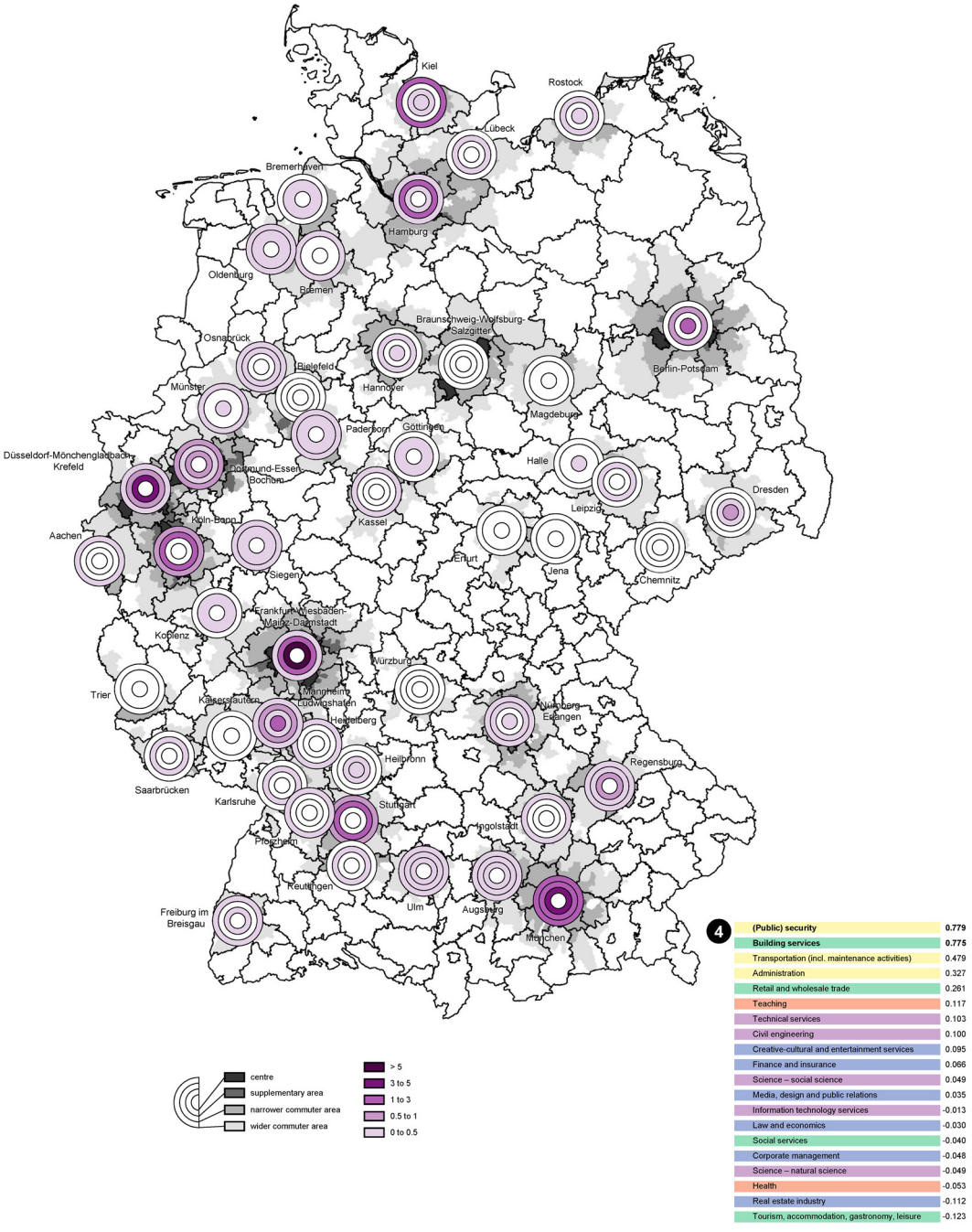

Figure 5: Principal component 4 – urban security and facility services. Own illustration.

commuting regions rather than remaining concentrated within the centres. The component therefore reflects the emergence of functionally integrated metropolitan labour markets in which advanced service activities are increasingly distributed across entire commuter regions of large cities (Cardoso and Meijers 2021a, 2021b).

In contrast, negative scores are observed in parts of eastern Germany and in several old industrial regions, particularly within the Rhine-Ruhr metropolitan area. In these regions, employment growth in advanced producer and creative services appears to be less important, suggesting either a stronger concentration of these activities in some urban centres (for example Köln-Bonn for the Rhein-Ruhr metropolitan area) or weaker diffusion into surrounding labour markets (Hipp et al. 2022; Kane et al. 2018). This pattern is consistent with differentiated regional

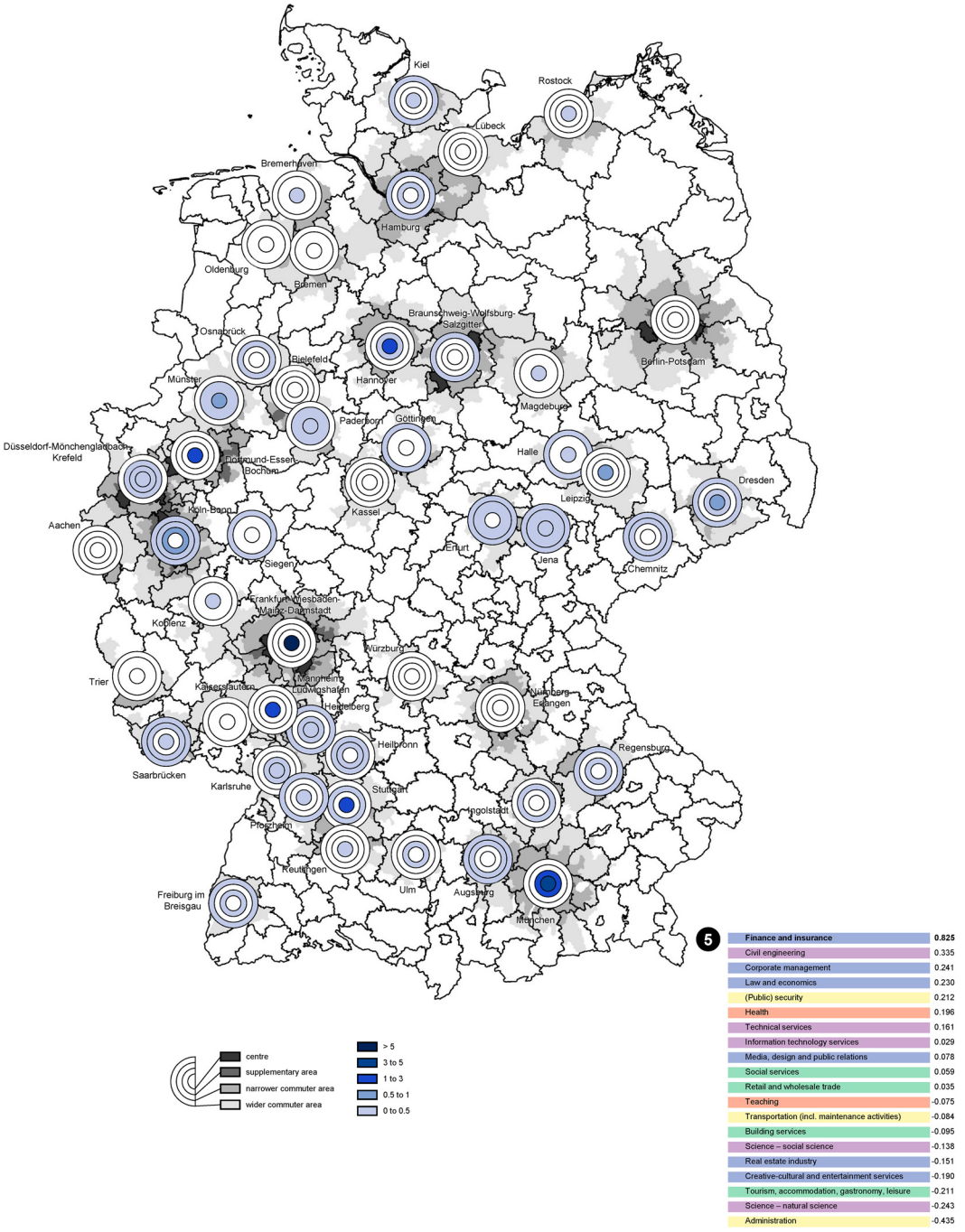

Figure 6: Principal component 5 – finance and insurance services. Own illustration.

innovation capacities and uneven development trajectories across European regions (Filippopoulous and Fotopoulos 2022).

Overall, the second principal component can be interpreted as a dimension of commercial and business-service regionalisation. High-scoring regions are characterised by the diffusion of employment growth in advanced producer services, management activities, information technology, creative industries, and commercial services across large city regions. The combination of retail and wholesale trade with highly specialised business services suggest that contemporary regionalisation processes increasingly link consumption-oriented and production-oriented activities that are often treated separately in established service typologies. The observed spatial pattern points towards functionally integrated large city labour markets in which

commercial demand, business services, and knowledge-intensive activities benefit from shared agglomeration economies. As a result, the component highlights the growing regional scale of service-sector development and reinforces the growing importance of large city regions as spaces of integrated economic development in Germany (Cardoso and Meijers 2021a, 2021b; Vidovich and Scolari 2022).

5.2.3 Principal component 3 – care and infrastructure services

The third principal component captures a distinct pattern of centralisation in employment growth centred on social services, health care and transportation activities (see Figure 4). These three occupational groups exhibit the highest positive loadings and therefore constitute the core dimension represented by the component. In contrast to the previous components, which were associated with advanced producer and knowledge-intensive services, this component reflects the spatial expansions of essential population-serving and infrastructure-related services across large city labour-market regions. This aligns with broader conceptualisations of service-sector differentiation between knowledge-intensive and socially necessary services in regional economies (Illeris 2005).

The spatial distribution of factor scores reveals a highly differentiated regional pattern. Strong positive scores are particularly evident in the large city regions of Munich, Nuremberg-Erlangen, Mannheim-Ludwigshafen, Cologne-Bonn, Düsseldorf-Mönchengladbach-Krefeld, and Hamburg, as well as several smaller large city regions in northwestern and central Germany. In these cases, employment growth in social sciences, health care and transportation is strongly confined to the centres. In contrast to the literature, which indicates a pronounced regionalisation of welfare-related and mobility-related services within functional labour-market regions, the analysis shows a strong concentration in urban centres for most parts of Germany.

A notable feature of regionalisation processes is the strong representation of southern German large city regions, particularly Bavaria, where many commuter regions exhibit positive factor scores. This suggests that employment growth in care and infrastructure services has increasingly dispersed across regions, reflecting both population growth and rising demands for care and mobility. This corresponds to empirical findings on suburbanisation, peri-urbanisation and the increasing functional integration of metropolitan regions, where population dynamics and residential mobility reshape service demands across the entire city regions (Münter and Osterhage 2018; Pagliarin and de Decker 2021). Conversely, many large city regions in northern and eastern Germany display weak or negative factor scores, indicating a lower degree of regionalisation. In these areas, employment growth in the respective sectors appears to remain less important or more concentrated in centres like for example in Leipzig or Hannover and Hamburg or is characterised by comparatively weaker overall growth dynamics.

Overall, the third principal component can be interpreted as a dimension of welfare and infrastructure services characterised by selective regionalisation alongside persistent centralisation tendencies. High-scoring large city regions are characterised by employment growth in social services, health care, and transportation activities, reflecting the increasing importance of population-serving functions within city-regional development. While many of these activities remain concentrated in urban centres, several dynamic large city regions – particularly in southern Germany – also exhibit evidence of diffusion into commuter areas. The component therefore reflects the growing integration of care, health, and mobility systems at the scale of the large city region. Rather than indicating complete decentralisation, the observed geography points towards an emerging city-regional service regime in which core cities continue to function as dominant service hubs while surrounding areas increasingly participate in the provision of welfare and infrastructure services. The findings suggest that demographic growth, suburbanisation, and rising service demand contribute to the formation of increasingly integrated systems of care, health and mobility within Germany's large city regions (Cardoso and Meijers 2021b; Münter and Osterhage 2018; Pagliarin and de Decker 2021).

5.2.4 Principal component 4 – urban security and facility services

The fourth principal component is primarily characterised by high positive loadings for the occupational groups (public) security and building services (see Figure 5). Its spatial distribution reveals a distinct pattern that points towards processes of regionalisation within German urban systems.

The map demonstrates that this process is particularly evident in several of Germany's large city regions. In the Rhine-Ruhr area, numerous suburban districts surrounding the major centres exhibit high component values, indicating that employment related to (public) security and building services is not concentrated exclusively within the central urban municipalities. Instead, the occupational structure associated with this component appears to be distributed

across the wider large city region. Similar patterns can be observed in the Munich large city region, where the wider commuter area display some of the highest component scores nationwide (Bentlage et al. 2021; Zhao et al. 2017). Elevated values are also visible in Frankfurt-Wiesbaden-Mainz-Darmstadt and Stuttgart, which are widely analysed as strongly integration metropolitan labour markets (Halleux et al. 2021; Wagner and Growe 2019). In these cases, the spatial pattern suggests that employment growth in the relevant occupational groups increasingly occurs in suburban locations.

This distribution reflects broader processes of metropolitan restructuring that have been documented in the economic-geographical literature. Building services are closely connected to the operation and maintenance of commercial properties, logistics facilities, public infrastructure, and residential developments. As these functions have increasingly expanded into suburban areas over recent decades, employment in related occupations has followed a similar trajectory (Shaw et al. 2020). Public security occupations are likewise influenced by suburban population growth and the spatial extension of critical infrastructure, transport networks, and public facilities. Consequently, both occupational groups tend to exhibit a stronger presence in large city commuter areas than in city centres alone, reflecting processes of regionalised sprawl (Vidovich and Scolari 2022).

At the same time, the observed regionalisation is neither complete nor spatially uniform. Several urban cores continue to display high component scores, suggesting that central-city locations remain important employment centres for these occupational groups (Berlin-Potsdam, Dresden, Ludwigshafen-Mannheim). Furthermore, substantial regional differences can be identified across Germany. While western and southern large city regions frequently exhibit strong suburban concentrations, many eastern German large city regions display weaker component values and less pronounced differentiation between centres and commuter areas. Northern Germany presents a mixed pattern, with some large city regions showing evidence of regionalisation while others remain comparatively neutral (Volgmann et al. 2022).

From an economic-geographical perspective, the component can therefore be interpreted as an indicator of the growing importance of city-regional maintenance and operational service economies within large city regions. The concentration of public security and building services in commuter areas reflects the functional decentralisation of activities associated with residential growth, infrastructure expansion, facility management, and the everyday operation of increasingly complex urban-regional systems. Rather than representing a simple relocation of employment away from city centres, the pattern points towards a polycentric urban structure in which suburban districts assume an increasingly important role in providing essential operational, maintenance, and security-related services. The component therefore highlights how regionalisation processes extend beyond knowledge-intensive activities and increasingly involve locally anchored services that support the functioning of large city regions and their expanding commuter areas (Urso 2021; Vidovich and Scolari 2022).

5.2.5 Principal component 5 – finance and insurance services

The fifth principal component is primarily defined by high positive loadings for finance and insurance, indicating a concentration of employment in finance and related business services (see Figure 6). In contrast to the previous components, the spatial pattern is strongly associated with operational or infrastructure-related functions and instead reflects the geography of higher-order service activities within Germany's urban system.

The map reveals a clear centre orientation of the component: High scores are concentrated in economically dynamic large city regions, particularly in the southern and western part of Germany, including Frankfurt-Wiesbaden-Mainz-Darmstadt, Stuttgart, Munich, Mannheim-Ludwigshafen, Dortmund-Essen-Bochum and Hannover. These regions are among the country's most important centres of corporate headquarters, financial services, insurance companies, and advanced business services (Hoyler et al. 2008). Elevated values are also visible in selected eastern Germany large city regions, although generally at lower intensity.

With regard to regionalisation, the pattern is more moderate than other principal components. Nevertheless, several large city regions exhibit positive scores not only in the urban core but also in surrounding suburban districts (Cardoso and Meijers 2021a). This is particularly evident in for example, Munich, and Köln-Bonn, where the commuter areas display relatively strong blue colouring. The presence of high component values in suburban municipalities suggests that finance- and insurance-related employment has become increasingly embedded within wider commuter areas (Vidovich and Scolari 2022). This development reflects the decentralisation of office-based activities, the emergence of suburban business park, and the growing functional integration of city-regional economies.

At the same time, the strongest concentrations remain closely linked to core centres. Consequently, the observed pattern should not be interpreted as a wholesale relocation of financial employment to the urban fringe. Rather, it points to a process of selective regionalisation, in which core cities retain their dominant command-and-control-functions while parts of the commuter areas of the large city regions increasingly participate in the production of advanced financial and business services (Urso 2021).

From an economic-geographical perspective, the component therefore reflects the continued importance of agglomeration economies in finance and insurance, combined with a gradual spatial extension of selected activities into commuter areas. Unlike the other principal components, finance and insurance emerge as a highly specialised and largely autonomous dimension of service-sector development, indicating that employment dynamics in this sector follow a distinct spatial logic. While some evidence of regionalisation can be observed in several large city regions, the strongest concentrations remain closely linked to core cities and their command-and-control-functions. Consequently, the observed pattern should not be interpreted as a wholesale relocation of financial ecosystem into surrounding areas. Rather, it reflects a process of selective regionalisation in which large city regions become increasingly integrated while core cities retain their dominant role in advanced financial services. The resulting geography combines the continued relevance of urban agglomeration advantages with broader trends towards polycentricity and city-regional economic integration (Castells 2010; Simmie and Strambach 2006; Urso 2021).

6 Synthesis and discussion: functional regionalisation beyond conventional service categories

The principal component analysis reveals a factor structure that differs considerably from established classifications of services activities into knowledge-intensive consumer services (KICS), knowledge-intensive business services (KIBS), technology-intensive knowledge-intensive business services (TKIBS), operational consumer services (OCS), and operational business services (OBS) (Glückler and Hammer 2013) (see also Table 4). While these categories are

Table 4: Overview of the different principal components and their composition. Own illustration.

Component	High-loading occupations	Interpretation	Explanation
Principal component 1	Information technology services (TKIBS) Media, design and public relations (KIBS) Teaching (KICS) Civil engineering (TKIBS) Tourism, accommodation, gastronomy, leisure (OCS) Administration (OBS) Corporate management (KIBS) Creative-cultural and entertainment services (KIBS)	Knowledge-intensive urban services with a strong emphasis on creative and administrative functions	Occupations benefit from agglomeration economies, diversified labour markets, and knowledge networks
Principal component 2	Retail and wholesale trade (OCS) Technical services (TKIBS) Law and economics (KIBS) Corporate management (KIBS) Creative-cultural and entertainment services (KIBS) Information technology services (TKIBS)	Commercial and business services	Combination of produced and market-oriented services expanding across large city regions
Principal component 3	Social services (OCS) Health (KICS) Transportation (incl. maintenance activities) (OBS)	Care and infrastructure services	Growth driven by population demands, care provision, and mobility needs
Principal component 4	(Public) security (OBS) Building services (OCS)	Urban security and facility services	Expansion of locally anchored services linked to residential and infrastructure development
Principal component 5	Finance and insurance (KIBS)	Financial and insurance services	Distinct spatial dynamics characterised by concentration in major centres

theoretically derived from the functional role of services within production and consumption systems (Tödtling and Trippl 2021), the extracted components reflect empirical co-location and co-evolution patterns of employment growth across large city regions in Germany. Consequently, the factor structure should not be interpreted as a contradiction of existing typologies but rather as evidence that contemporary (regionalisation) processes cut across traditional sectoral boundaries.

The first principal component combines information technology services, media and public relations, teaching, civil engineering, tourism and hospitality, administration, corporate management, and creative-cultural services, while social sciences and real estate activities load negatively. This mixture of TKIBS, KIBS, KICS, OCS and OBS suggests that the component captures a broader metropolitan growth dynamic rather than a specific service category. The common characteristic of the positively loading occupations is their dependence on large and diversified urban labour markets, dense knowledge networks, and highly educated workforces. Such combinations have frequently been described in the literature as characteristics of metropolitan knowledge economies in which creative, administrative, educational, and technological functions increasingly co-locate. The negative loadings of social sciences and real estate indicate that these activities follow different spatial trajectories, possibly reflecting stronger concentration in core cities and less diffusion into large city commuter areas.

The second component is dominated by retail and wholesale trade, technical services, law and economics, corporate management, creative-cultural services, and information technology. Although these occupations originate from different theoretical categories, they share a strong orientation towards market-mediated interactions and metropolitan demand. Particularly noteworthy is the combination of operational consumer services such as retail trade with highly specialised business services. This finding supports arguments that advanced producer services increasingly depend on large metropolitan consumer markets and benefit from the same agglomeration economies that support retail and commercial functions (Daniels 1991; Taylor et al. 2013). The factor thus reflects the emergence of integrated metropolitan service economies rather than distinct functional sectors.

The third component is characterised by high loadings for social services, health care, and transportation activities. Unlike the first two components, this factor is strongly associated with population-serving functions. These activities are typically linked to demographic demand and everyday service provision rather than knowledge production or business support. Their joint appearance suggests a process of regionalisation driven by suburban population growth and the expansion of metropolitan service infrastructures (Growe and Volgmann 2022). Similar developments have been described in studies of welfare and care economies, which emphasise the increasing spatial dispersion of health and social services across functional urban regions (Andrews and Kearns 2005). The inclusion of transportation services further highlights the importance of accessibility and commuting systems in supporting these decentralised service networks.

The fourth component combines public security and building services, two occupations generally assigned to different theoretical categories. Their empirical association may reflect shared dependence on locally anchors service provision and public infrastructure. Both activities are closely tied to residential expansion, facility management, and the maintenance of the built environment. From a regional perspective, the component may therefore represent the territorial extension of basic urban services into suburban and peri-urban areas.

Finally, the fifth component consists solely of finance and insurance. The emergence of a separate factor indicates that employment dynamics in this sector are largely independent of broader service-sector developments. This finding corresponds to extensive literature describing finance services as one of the most spatially selective and functionally specialised segments of the service economy (Sassen 2001). Financial activities tend to concentrate in a limited number of large city centres and are often governed by global rather than regional dynamics. Consequently, their regionalisation pattern differs fundamentally from that to other advanced services.

Overall, the results suggests that regionalisation processes in large city regions are structured less by traditional service-sector classifications than by common spatial development dynamics. Employment growth appears to be organised around distinct regionalisation regimes: an urban knowledge-economy regime (Principal Component 1), an advanced market-service regime (Principal Component 2), a welfare and infrastructure regime (Principal Component 3), a local urban-service regime (Principal Component 4), and a highly specialised finance regime (Principal Component 5). The findings therefore support recent economic-geographical perspectives that emphasise functional urban regions and relational economic networks as key determinants of spatial development, often transcending conventional sectoral boundaries.

7 Conclusions

The analysis demonstrates how different service categories developed spatially across Germany's large city regions between 2012 and 2025. It becomes evident that service-sector development in Germany's large city regions is characterised by distinct spatial dynamics that vary considerably between service categories. While knowledge-intensive business services remain closely associated with metropolitan environments, their growth is no longer confined to core cities. Instead, dynamic developments increasingly occur in commuter areas and secondary centres, indicating a growing regionalisation of metropolitan service economies. Operational and consumer-oriented services exhibit even broader spatial distributions, reflecting their stronger dependence on population dynamics, local demand, and the functional organisation of city-regional labour markets.

At the same time, the study reveals the extent to which service categories are associated with distinct functional patterns within large city regions. Regionalisation does not follow a uniform trajectory across all service activities. Some functions remain strongly concentrated in large urban centres, whereas others increasingly spread throughout wider city regions. This pattern suggests that contemporary service-sector development is shaped by a combination of agglomeration economies, demographic dynamics, and growing functional integration between urban cores and surrounding areas. Consequently, large city regions rather than individual cities emerge as the most relevant spatial framework for understanding the geography of the service economy.

A central finding of this study is that the empirical structure of service-sector development only partially corresponds to established service classifications like the service typology proposed by Glückler and Hammer (2011, 2013). While the categories KICS, KIBS, TKIBS, OCS and OBS remain useful for characterising individual service activities, the principal component analysis reveals broader functional dimensions that cut across conventional sectoral boundaries. Occupations from different service categories frequently co-evolve and co-locate within similar city-regional contexts.

This suggests that regionalisation processes are driven less by sector-specific characteristics than by shared spatial development logics. The identified components point to broader city-regional development regimes, including knowledge-intensive urban functions, commercial and business-oriented activities, welfare and infrastructure services, operational metropolitan services, and highly specialised financial functions. The findings therefore support perspectives that emphasise functional urban regions and relational economic organisation over strictly sectoral interpretations of spatial development.

Furthermore, the findings highlight the importance of adopting a city-regional perspective when analysing economic development and designing future growth strategies. The increasing presence of service-sector growth in commuter areas indicates that surrounding municipalities are no longer merely dependent extensions of core cities. Instead, they contribute specialised functions to metropolitan economies and participate actively in regional transformation processes. This observation aligns with recent discussions on regionalisation, polycentric development, and the growing role of secondary centres within large urban regions.

From a planning perspective, these developments suggest that economic development strategies should move beyond administrative boundaries and focus on functional urban regions. Labour markets, transport systems, knowledge infrastructures, and service provision increasingly operate at the city-regional scale. Supporting these interdependencies may therefore become a key task for regional planning and governance. In particular, the emergence of specialised service functions in commuter areas highlights the need for stronger cooperation between core cities and surrounding municipalities.

Several limitations should be considered when interpreting the results. First, the analysis is based on occupational employment data and therefore captures functional labour-market structures rather than firm-level dynamics, business networks, or organisational relationships. While occupations provide valuable insights into the functional composition of regional economies, they cannot fully account for the interactions between firms and institutions that shape regionalisation processes.

Second, the analysis focuses exclusively on Germany's large city regions. The identified patterns are therefore influenced by the specific characteristics of the German urban system, including its comparatively polycentric settlement structure and dense network of small and medium-sized cities (see also Terfrüchte and Growe 2024). Furthermore, the results are contingent upon the predefined delineation of large city regions. Although the classification is functionally grounded in commuting relationships and provides a well-established framework for analysing city-regional development, alternative regional delineations may lead to somewhat different spatial configurations and empirical patterns.

Finally, principal component analysis identifies patterns of co-variation and common development trajectories but does not permit causal conclusions regarding the mechanisms driving regionalisation. The results should therefore be interpreted as evidence of underlying spatial structures rather than direct explanations of regional economic change.

The findings open several avenues for future research. A first priority is the comparative investigation of service-sector regionalisation across different national urban systems. Such analyses could determine whether the functional dimensions identified in Germany represent a broader feature of contemporary service economies or reflect country-specific institutional and spatial conditions. Comparative studies may also improve our understanding of how metropolitan structures influence service-sector development.

A second avenue concerns the integration of relational perspectives on regionalisation processes. Existing relational research has provided important insights into the network structures of advanced producer services and other knowledge-intensive activities. However, the occupational approach adopted in this study captures a much wider range of service functions across large city regions. Combining occupational structures with relational indicators such as commuting patterns, business networks, knowledge exchanges, and innovation linkages could therefore provide a more comprehensive understanding of how diverse service activities shape city-regional development and regionalisation over time.

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