DECENTRALISATION AND FUNCTIONAL SPECIALISATION IN SUPER MEGA-CITY REGIONS: CHANGING FUNCTIONAL PATTERNS OF MANUFACTURING AND KNOWLEDGE-INTENSIVE BUSINESS SERVICES ACTIVITIES IN THE POLYCENTRIC SUPER MEGA-CITY REGION OF THE PEARL RIVER DELTA

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With 5 figures and 4 tables
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Summary: This article deals with the processes of decentralisation and functional specialisation in the Chinese mega-city region of the Pearl River Delta (PRD). The PRD is one of the three largest mega-city regions and is the most polycentric of the three. Spatial changes in economic activities from 2000 to 2010 were analysed, based on occupational data. This analysis showed that, on one hand, the large centres are undergoing an upgrade and the range of occupations in formerly predominantly industrial centres has been expanded to include high-quality service occupations. On the other hand, decentralisation processes of economic activities in the hinterland were observed. In the formerly small economic centres in the hinterland, industrial activities, in particular, are on the increase. Service occupations continue to be concentrated in the large centres.

Zusammenfassung: Der Beitrag befasst sich mit Dezentralisierungsprozesse und Prozessen funktionaler Spezialisierung in der Chinesischen Mega-City Region Perlflussdelta. Das Perlflussdelta ist eine der drei größten Mega-City Regionen und - von diesen drei Regionen - die am stärksten polyzentral strukturierte Region. Auf der Grundlage von Berufsdaten wird die räumliche Veränderung wirtschaftlicher Aktivitäten im Zeitraum von 2000 bis 2010 analysiert. Die Analysen zeigen, dass zum einen die großen Zentren einen Aufwertungsprozess durchlaufen, und das in ehemals vorwiegend industriellen Zentren das Berufsspektrum um hochwertige Dienstleistungsberufe erweitert wird. Zum anderen können Dezentralisierungsprozesse ökonomischer Aktivitäten in das Hinterland beobachtet werden. In ehemals kleinen ökonomischen Zentren im Hinterland nehmen vor allem industrielle Aktivitäten zu. Dienstleistungsberufe sind weiterhin in den großen Zentren konzentriert.

Keywords: urban geography, economic geography, China, metropolitan area, mega-city region, polycentricity

1 Introduction

With China's increasing integration into global economic processes since the 1980s, development in the three largest mega-regions - Beijing-Tianjin-Hebei (BTH), the Yangtze River Delta (YRD) and the Pearl River Delta (PRD) - has experienced particular dynamism (Duan et al. 2017; Li et al. 2018). The PRD region, in particular, has been mentioned in the literature as a prominent example of such development, with a change in relationship between front shops and workshops, with Hong Kong being the front shop and the PRD being the "workshop of the world" (Schiller et al. 2015; Yeh et al. 2015; Zhang and Kloosterman 2016, 1070).

Specific aspects of the development of Chinese mega-regions that have been analysed include: the description of polycentric mega-regions and the measurement of polycentricity in these regions (Liu et al. 2016; Zhang et al. 2017); the evolution of Chinese mega-regions as special types of super mega-regions (Yeh and Chen 2020); networking within polycentric mega-regions, and the integration of mega-regions in national and international business networks (Li et al. 2018; Li and Phelps 2018); and changes in the economic structures of the mega-regions (Meyer et al. 2012; Yeh et al. 2017; Zhong and Yan 2008).

Different with their Western counterparts, both manufacturing industries and producer services play important roles in the formation and spatial structures of mega-city regions in China. However, the surrounding PRD region hosts several large cities, including Guangzhou and Shenzhen, which have gained importance not only as manufacturing locations, but also as centres of services provision (Schiller et al. 2015; Yeh et al. 2017).

This paper analyses the spatial changes of economic functions that have resulted from economic catching-up in PRD, based on employment data for the years 2000 and 2010. The PRD was used as a case study to illustrate the extent to which the idea of functional urban specialisation (as introduced by Duranton and Puga 2005) can be used to explain spatial evolution inside a polycentric mega-city region, in the context of technological upgrading, and institutional development in China. The PRD has been recognised as China's top super mega-city region for many years (Hall 1999; Yeh and Chen 2020), and previous analyses have determined that there has been a great expansion of economic activities into the hinterland of the PRD (Zhao et al. 2017a). Following these observations, we argue that economic catching-up processes in super mega-city regions lead to a decentralisation of economic functions within the region while, at the same time, a change of locations of economic functions can be observed, leading to new forms of functional specialization between the multiple cores and the hinterland within the region. The aim of this paper is to contribute to the understanding of polycentricity in the context of fast growing super mega-city regions in the basis of new empirical findings.

In this paper, Section 2 introduces the conceptual framework of the interrelatoin of catching-up processes (see section 2.1), changing core-hinterland-relations in polycentric regions (see section 2.2.) and changing functional pattern (see section 2.3). Section 3 explains the data, study area and methods used in the empirical analysis (Section 4). In Section 5, the key findings are summarised. A conclusion with a discussion is offered in Section 6.

2 Changing economic specialisation in polycentric super mega-city regions

Our hypothesis of changing functional patterns in polycentric super-mega city regions as result of catching-up processes assumes an interrelation between catching-up processes (see section 2.1), changing spatial patterns of the core-hinterland-relations in polycentric regions (see section 2.2.) and changing functional pattern (see section 2.3).

2.1 Catching-up processes in Chinese super mega-city regions

In analysing Chinese urbanisation processes and economic development, mega-cities have recently come into focus. The emergence of new spatial configurations in the form of an "extensive archipelago of large urbanized regions" (Zhao et al. 2017b, 148) has resulted in a fast-evolving body of literature, using a variety of terms, such as global city-region (Scott 2001), mega-city region (Hall and Pain 2006), polynuclear urban region (Turok and Bailey 2004) and metropolitan region (Growe 2012), each associated with different theoretical concepts.

Some of the mega-city regions are centred around at least one mega-city, with a minimum of 10 million inhabitants, although, in some cases, there is more than one. Especially along the Chinese coastline, substantial economic development has resulted in so-called "super mega-city regions" (Yeh and Chen 2020, 636), consisting of several large centres and their hinterlands. The dimensions of these spatial configurations are extraordinary, and further study is required, especially of centre-hinterland relations. Following Yeh and Chen (2020), we use the term 'super mega-city region' in this work.

What is the background to these fast evolving changes? Until the economic reform at the end of the 1970s, Chinese cities had a rather compact morphological structure. Also, until the opening up of China, peripheral areas had been relatively underdeveloped (Wu 2016; Yeh and Chen 2020). However, the economic reform in China that began in 1978 led to unprecedented population expansion and economic growth, which has mainly affected regions such as BTH, the YRD and the PRD. Covering only 5% of the national land area, about 24% of the Chinese population lives in these three super mega-city regions (Yeh and Chen 2020). In addition, in 2017, more than 39% of the national gross domestic product (GDP) was contributed from these three regions.

Traditionally dominated by one or two centres (e.g. the BTH region is dominated by Beijing and Tianjin, the YRD by Shanghai and the PRD by Guangzhou), the transition brought by urbanisation, the market economy and globalisation resulted in more polycentric urban patterns in Chinese mega-city regions. The political and planning reaction to this development was to support strategic plans and provide land-based municipal finances that created new cities and grew existing cities in the hinterlands of the large centres. This emergence of new cities has also been driven by rural transformation development (Lin 2002; Yeh and Chen 2020).

To summarise, the potential to integrate super mega-city regions into global economic networks has been considerably supported by planning and politics, leading to the decentralisation of economic

activities into the region and the transformation of former economic patterns in the hinterland, as well as in the multiple cores.

2.2 Changing relations between multiple cores and the hinterland in polycentric super mega-city regions

Regarding urban population developments, city regions in inland China are predominantly characterised by a monocentric structure, with a primate city (Liu et al. 2018). However, the three coastal mega-city regions are considered to show high polycentricity and, of these three mega-city regions, the PRD is considered as having experienced the most drastic increase in polycentricity, following China's reforms in 1978 (Lin 2001; Wei et al. 2017). How should we understand 'polycentricity' in this context?

Although multiple understandings of polycentricity exist in spatial analyses, Schmitt et al. (2015) differentiated two main perspectives on a regional scale, which have been picked up in recent systematisations of polycentricity (Münter and Volgmann 2020; Shu et al. 2020). The first perspective refers to "a 'city-regional' scale" (Schmitt et al. 2015, 4). Cities and their surroundings are considered here in terms of a labour market region, with commuter linkages being emphasised. Schmitt et al. (2015) associated this perspective with the terms 'intra-urban patterns' or 'intraurban polycentricity' of Kloosterman and Musterd (2001). Mentioning Los Angeles, London and Paris as examples of intraurban polycentricity, Kloosterman and Musterd (2001) argued that socio-economic changes – such as an increase in double-income households and the associated changes in commuter flows, as well as an increase in knowledge-based work and the associated importance of face-to-face interaction – create urban-regional landscapes with several economic cores around previously monocentric core cities (see also Shu et al. 2020).

The second perspective focuses on polycentricity on "a 'mega-regional' scale" (Schmitt et al. 2015, 4). This view deals with the growing together of formerly morphologically separated cities into a dense polycentric network of cities. It has been linked with the idea of 'interurban patterns' or 'interurban polycentricity' by Kloosterman and Musterd (2001). The reasons for the development of interurban patterns are similar to those for the development of intra-urban patterns, but are based on other spatial structures - namely, several closely-situated cities that were historically rather independent of each other. Spatial proximity and socio-economic changes result in a functional integration between the cities, culminating in interurban polycentricity (Hall and Pain 2006; Lüthi et al. 2010; Meijers and Burger 2010). Using the examples of the Randstad in the Netherlands and the Kansai region in Japan, Kloosterman and Musterd (2001) determined that the understanding of interregional polycentricity goes beyond a single city and, thus, non-urban spatial land uses can be included in the polycentric network, too (Davoudi 2007). For example, agricultural areas may be located in the middle of a network of closely-intertwined cities in regions with interurban polycentricity.

With regard to polycentric development in super mega-city regions, we argue that the two main perspectives on polycentricity have to be understood together, as both sides of one coin. Because super mega-city regions contain, by definition, at least one city with more than 10 million inhabitants, intraurban polycentricity is expected to provide more than just one centre for work and supply. At the same time, the prevailing assumption, when it comes to understanding polycentric mega-city regions, is that this type of spatial structure makes it possible to develop different specialisations across the entire region, by using infrastructure and complementary spatial advantages that exist within the region (De Goei et al. 2010). Thus, polycentric development in super mega-city regions is expected to lead to "increasing interconnections, synergies and complementarity among the centres" (Münter and Volgmann 2020, 7), as well as to "increasing interconnections, synergies and complementarity among the centre and its subcentres" (Münter and Volgmann 2020, 7).

2.3 Changing functional patterns in Chinese super mega-city regions

Compared to urban agglomerations in Western countries, super mega-city regions in China have only relatively recently been integrated into global economic processes (Wu 2016; Yeh and Chen 2020). From an economic perspective, the traditional centres of super mega-city regions have developed as regional anchors within global economic networks. In the huge cores of the super mega-city regions, economic services have developed, linking the regions with the economic networks outside China, whereas the hinterlands in super mega-city regions have served as blue-collar work places (Zhang and Kloosterman 2016). With regard to the PRD re-

gion, Hong Kong has been viewed as a global anchor in service networks, while the PRD has been understood to be a manufacturing-related hinterland of Hong Kong, described as the "workshop of the world" (Zhang and Kloosterman 2016, 1070).

However, this situation has changed substantially in the last two decades. The growing service activities in the PRD's economy are partly the result of China opening up the service market after its accession to the World Trade Organisation in 2001, as well as the unveiling of the 10th Five-Year Plan (2001–2005), launched with an initial policy of externalising markets for the service sector (Yeh and Chen 2020).

This structure mirrors one form of functional specialisation, as introduced by Duranton and Puga (2005), who argued that changing functional patterns could be seen as the result of globalised production processes. Duranton and Puga (2005) understood specialisation as being function-dependent (e.g. having management and control functions) rather than sector-dependent (e.g. the chemical industry). They assumed that the locations of manufacturing firms could be more easily transferred to small cities and, due to lower land rents, to the surrounding regions. By contrast, management functions remain agglomerated in the core cities. Thus, economic clusters evolve across traditional sectoral boundaries, resulting in functional, rather than sectoral, specialisation. Following their argument, different spatial patterns might be expected between the localisation of services and the localisation of manufacturing, leading to service clusters and manufacturing clusters rather than different sectoral production clusters (e.g. computer production, where production and headquarters are located in direct proximity) (Schiller et al. 2015).

This division is influenced by differing levels of importance of the transportation costs and spatial requirements between the manufacturing and services industries. Accordingly, a decrease in transportation costs would result in different choices of locations for manufacturing firms compared with those that provide services. Transportation costs are more important for manufacturers than for service providers. Even if transportation costs are low for service providers, the production of these services is based on complex interactions (Sharmeen et al. 2014; Growe 2019a) and, therefore, transaction costs come to have a crucial role. Dense agglomerations facilitate face-to-face interactions (Boschma 2005; Torre and Rallet 2005; Boschma and Iammarino 2009), and the organisation of business activities via information and communications technology (ICT) and meetings in physical colocation (Denstadli and Gripsrud 2010; Torre 2015; Grabher et al. 2018). Furthermore, a critical mass of potential interaction partners and the infrastructure for facilitating personal meetings, such as airports or trade fairs, can be found in dense agglomerations (McNeill 2009; Growe 2019b).

With regard to spatial requirements, service activities, especially KIBS activities, are carried out in offices and, thus, are less space consuming than manufacturing activities. They may be organised in high-rise buildings in central locations, in close proximity to important infrastructure, such as universities, airports and high-speed train stations, and trade fair locations. This infrastructure facilitates the exchange of knowledge through enabling the movement and interaction of knowledge holders (Aslesen and Jakobsen 2007; Shearmur 2012; Wang et al. 2016). Manufacturing activities, however, are carried out in factories, requiring more space for production sites, logistics and transportation infrastructure. Central locations with high land prices are, thus, less attractive. More important are low land prices and transportation routes with less traffic than in central locations. Consequently, economic catching-up processes in core locations may lead to a displacement of manufacturing activities in central locations, while less space-consuming and high-income activities increase in central locations (Schiller et al. 2015).

Following this argumentation, we assume that economic catching-up processes in super mega-city regions lead to a decentralisation of economic functions within the region, while, at the same time, a change in locations of economic functions can be observed, leading to new forms of functional specialisation between the multiple cores and the hinterland within the region. Based on this assumption, this paper aims to answer two questions, each dealing with changing patterns that have been induced by economic catching-up processes in China.

- The first question deals with changing patterns of importance in polycentric super mega-city regions, and is based on the assumption that the two main understandings of polycentricity coincide with each other in these regions: Can we observe increasing intraurban polycentricity alongside decentralisation processes within the PRD?
- The second question deals with changing functional patterns in polycentric super mega-city regions, and is based on the assumption that economic catching-up processes lead to a dis-

placement of manufacturing activities in central locations, and their decentralisation, while, at the same time, KIBS activities increase in central locations that have formerly been blue-collar-workplaces: Can we observe changing functional patterns in the multiple cores and the hinterland of the PRD?

3 Data, methods and study area

The following section introduces the databases used to analyse the specialisation processes in operation in the super mega-city region of the PRD.

3.1 Knowledge-intensive business services and manufacturing in the PRD

Much research, aimed at trying to conceptualise, and identify developments in, polycentric regions in China, has dealt with the polycentric development of the three most prominent super mega-city regions (BTH, YRD, and PRD). Either by analysing the importance of the individual centres, using attribute data for the different cities (mainly population and employment data) (e.g. Meyer et al. 2012; Schiller et al. 2015; Zhong and Yan 2008 for analyses of the PRD) or by analysing the relations among the centres, using commuter data or corporate firm network data (e.g. Yeh et al. 2015; Zhang 2018; Zhang and Kloosterman 2016; Zhao et al. 2017b for analyses of the PRD).

Although changing relations between spatial units can best be analysed through relational data, an approach based on occupational data was used to analyse changing polycentric and functional patterns in the PRD due to data availability. Occupational data was provided by the Statistics Bureau and Population Census Office (SBRCO) of Guangdong Province, China. The aggregated numbers of employees in different professions were collected using a sample that included 10% of all residents aged over 15 years (Tab. 1)[1]. The professions were classified and differentiated using occupational codes for 1999, including careers in manufacturing and the services; self-employed people were also included (GB/T 6565-1999, Chinese Standardisation Administration). Using this data, the employee numbers were estimated for each type of profession, rather than using business classified by sector (for a sectoral analysis, see Wang et al. 2016; Yeh et al. 2017). Some scholars have analysed the functional division of labour by region or nation, by evaluating the business activities of the cross-border investment projects of foreign multi-national corporations (Burger et al. 2013; Schiller et al. 2015). However, this approach does not provide a complete picture of functional specialisation in space because domestic activities are excluded (Schiller et al. 2015). This might lead to a skewed result, as domestic firms are also dominant players in regional economies in the new millennium (Wang et al. 2016). Following functional polycentric mega-city research through the lens of the knowledge-intensive business services (KIBS) professions (as conducted, for example, by Growe 2016; Hall and Pain 2006), we argue that occupational data can provide a better map of functional divisions in the PRD because they reflect the activities provided in the region.

The classification of employees by occupation depends on the type of activity being performed currently, rather than on recent activities or qualifications. The data refers to the location of residence of the employees, which may result in an overestimation of the importance of central locations for KIBS activities. However, the understanding of manufacturing locations will be less influenced by this because usually manufacturing workers live at dormitories or shared rent flats within or near their factories. For our analysis, we focused on manufacturing and service related occupational groups. The former groups involved manufacturing and common intermediary services, while the latter groups involve the KIBS workers (Tab. 1). Agricultural occupational groups are not included.

Two datasets, from 2000 and 2010, were used to allow a comparison over time. These are the latest data released by the government as the results of the census of 2020 are pending. However, the data allows investigating economic changes in space after China joined the World Trade Organisation and after the initiation of a service orientated economic policy in 2001. The data were provided at the county level (see Fig. 1) - the smallest spatial unit available for the public to acquire data from. The delimitation of the counties enabled a differentiation between the core cities and their hinterlands, which is suitable for studying specialisation in the super mega-city region.

[1] The Chinese population census contains a short survey (with basic information, e.g. about gender and age) or a long-table surveys (containing detailed information about occupations, family status and living conditions). Due to time efficiency and cost savings while conducting surveys within the large population of China, the central government defines a 10% sample as suitable scale for long-table surveys in every province. Surveyors randomly choose 10% of households in every residential community.

Tab. 1: The numbers of employees by occupation in the Pearl River Delta

Occupation type	Code	Number of occupants in the 10% sample			Share of occupation type in all professions in the PRD (%)		
		2000	2010	Increase rate (%)	2000	2010	Change
Head of business	0-5	54,330	113,342	108.6	2.1	3.3	1.2
Scientific researchers	1-1/1-2	804	2,065	156.8	0.0	0.1	0.1
Engineers	1-3/1-4 /1-5/1-6	32,616	79,402	143.4	1.3	2.3	1.0
Economic business personnel	2-1	54,236	78,007	43.8	2.1	2.3	1.2
Financial staff	2-2	10,465	25,014	139.0	0.4	0.7	0.3
Legal staff	2-3	1,561	3,214	105.9	0.1	0.1	0.0
Literary and artistic staff	2-5	4,266	14,918	249.7	0.2	0.4	0.2
Administrative office staff	3-1	89,573	199,114	122.3	3.5	5.7	2.2
Postal and telecommunications business personnel	3-3	7,079	11,139	57.4	0.3	0.3	0.0
Purchasing and sales personnel	4-1	259,134	490,962	89.5	10.1	14.2	2.1
Warehouse personnel	4-2	28,186	51,792	83.8	1.1	1.5	0.4
Machinery manufacturing and processing staff	6-6	89,373	102,967	15.2	3.5	3.0	-0.5
Electromechanical assembly personnel	6-7/6-8/6-9	123,163	185,449	50.6	4.8	5.4	0.6
Machinery and equipment repair personnel	7-1	31,857	30,375	-4.7	1.2	0.9	-0.3
Electronic components and equipment manufacturing, installation, debugging and maintenance staff	7-3	96,054	215,948	124.8	3.7	6.2	2.5
Rubber and plastic products production personnel	7-4	45,462	55,599	22.3	1.8	1.6	-0.2
Textile, knitting and dyeing personnel	7-5	50,704	53,066	4.7	2.0	1.5	-0.5
Cutting, sewing and leather product	7-6	219,567	260,033	18.4	8.5	7.5	-1.0
Wood, wood-based product personnel	8-1	49,697	57,325	15.3	1.9	1.7	-0.2
Craft, art production staff	8-6	89,246	56,284	-36.9	3.5	1.6	-1.9
Transport equipment operators	9-1	69,913	87,661	25.4	2.7	2.5	-0.2
Inspection, measurement personnel	9-2	59,774	77,497	29.7	2.3	2.2	-0.1
Sum		1,467,060	2,251,173	53.4	65.9	74.7	2.4

Source: own calculations, based on data from the SBRCO of Guangdong Province, China

It should be noted that some of the borders of the counties in the PRD changed over the 10-year period. We made relevant adjustments to accommodate these changed spatial units so that a comparison of the specialised patterns between 2000 and 2010 was possible. The county-level administrative boundaries that existed in 2000 were used to delineate our sub-regions, with the exception of the borders of Huiyang and Huicheng. For example, Dongshan, Fangcun, Luogang and Jinwan were merged into Yuexiu, Liwan, Baiyun and Doumen, respectively. In addition, Dongguan and Zhongshan are both prefecture-level cities that administrate over only one county. The quality of this data was not perfect, but was in line with that used in ongoing research.

Using this, we produced a dataset that included occupational information for 2000 and 2010 for 45 counties (or districts), in nine cities at or above prefecture level, in the PRD (Fig. 1).

3.2 Study area: the Pearl River Delta (PRD)

The PRD was used as a case study to illustrate the changing functional patterns in polycentric Chinese super mega-city regions for two reasons:

First, the spatial structure of the PRD supports analysis of the general changes occurring in polycentric city regions. The PRD was already being recognised as China's top mega-region in the 1990s (Hall 1999). Together with the YRD, the PRD is structured more polycentric than any other Chinese mega-city region, including BTH (Liu et al. 2018).

Second, the economic structure of, and developments occurring in, the PRD support the analysis of general functional changes in polycentric city regions. A comparison of the intercity connection between the PRD and YRD, based on headquarter-branch relations, has indicated that businesses in the PRD are more likely to set up branches beyond prefecture boundaries (Zhao et al. 2017a), implying that an analysis of the increasing functional specialisation in any one polycentric region could be analysed in the PRD.

The PRD is one of four super mega-city regions in China (Yeh and Chen 2020). Of these, the PRD is the only super mega-city region that exists in only one Chinese province. Its territory covers 42,200 km^2. In 2010, there were 56.1 million people living there, with a rate of increase between 2000 and 2010 of 30.9%. The population is highly agglomerated. Guangzhou and Shenzhen, the two mega-cities in the PRD, have population densities of over 10,000 per km^2 in their central districts (Fig. 1), with their total populations exceeding 10 million people in 2010. Although the population density in Dongguan and Foshan was lower, they have also developed into big cities, with populations exceeding 5 million people each. In contrast, the peripheral counties were much less appealing to residents, and were peppered by small towns with rural characteristics. Overall, the city system in the PRD consisted of various levels of settlement, and this may have had an influence on its differentiation and the shift in functions.

Figure 1 also shows that Hong Kong and Macao, the two special administrative regions in China, are

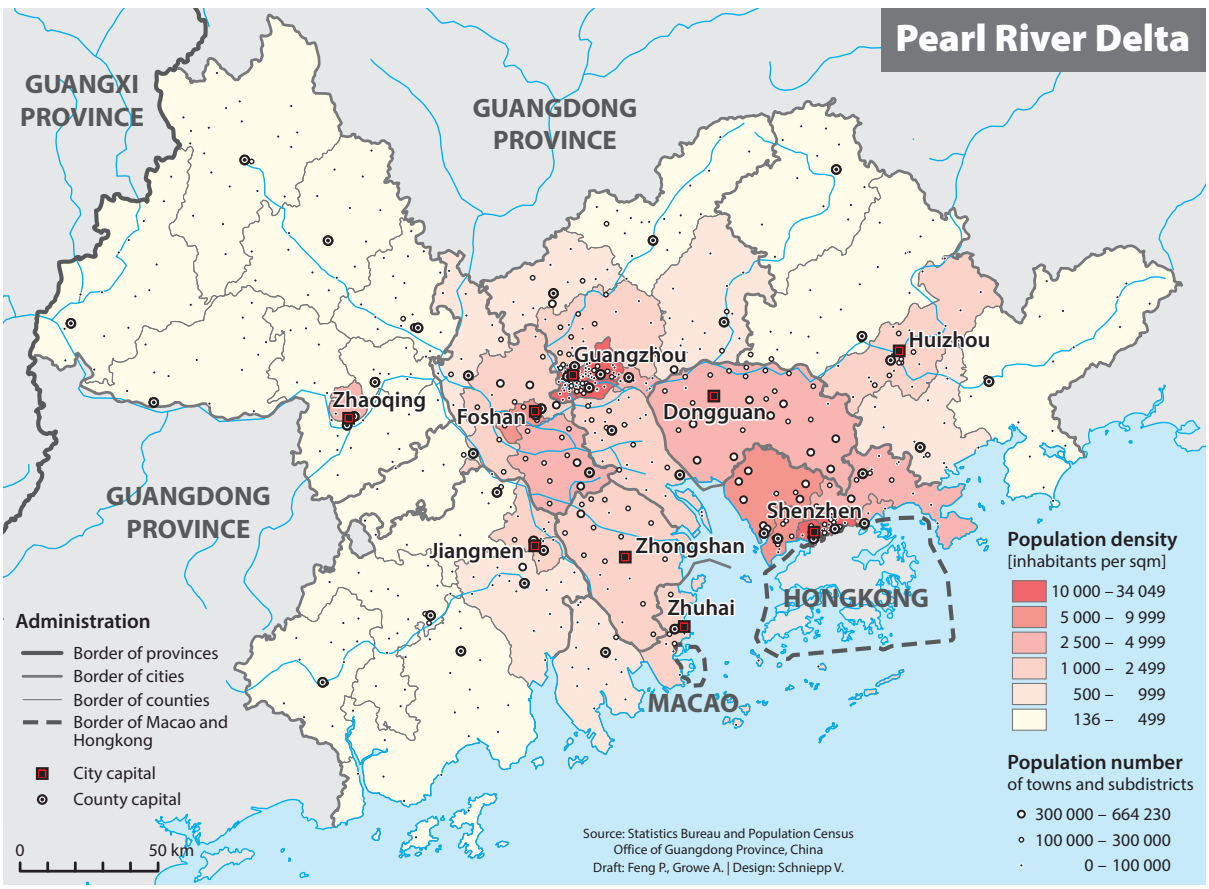


Fig. 1: The Pearl River Delta and the 45 counties and nine cities analysed. Source: author's modifications based on original layers from the Chinese National Catalogue Service for Geographic Information: www.webmap.cn

not part of the analysis. Hong Kong and Macao highly influence the development of the PRD. However, the institutional differences between the PRD and Hong Kong or Macao also result in different statistical classifications in their censuses. Thus, a comparison or simultaneous use of the data of both censuses is not possible.

3.3 Methods

Changing spatial patterns can be analysed with a number of methods. To identify spatial and functional changes without ex-ante aggregation of functional components, a principal component analysis (PCA) is applied in this study. This enables identifying spatial interrelating functions and sheds light on the shifting positions of the various cities and regions in the city system of the PRD. Following Growe (2016), PCA was used to detect correlations between gains and losses in the different economic functions among all the counties in the PRD. Data from all 45 counties for 2000 and 2010 were compared, based on relative changes. The first step was to compute the share of each county in the PRD, in terms of all employees engaged in a function in 2000 and 2010, respectively. The second step was to calculate the percent change in each county's share in a function between 2000 and 2010. The third step involved z-standardising the changes, resulting in values that measured whether the change in importance of a spatial unit, as a location for employees in KIBS or manufacturing, was above or below average in the PRD. This last value was termed the 'change in importance' (CI) value by Growe (2016). Twenty-two CI-values were calculated for each of the 45 counties. The average of the z-standardised values was 0, with standard deviations of 1 and -1. The z-standardised change in importance can therefore be interpreted as follows:

- CI-values of between -1 and 1 indicate a small change;
- CI-values of between -2 and -1 and between 1 and 2 indicate a medium-sized change; and
- CI-values of > 2 or <-2 indicate exceptional change, in statistical terms.

Based on these CI-values, one dynamic PCA was performed. PCA has been verified as a technique for detecting patterns of similar development in advanced producer services or KIBS by reducing multiple indicators to a few components (Growe 2016; Taylor et al. 2014; Taylor and Walker 2001). We extended the application of this method to all the economic activities listed in Tab. 1.

Before applying a dynamic PCA to the CI-values, a structural PCA (based on occupation percentage in each county in 2000) was performed to help in the interpretation of the results of the dynamic analysis, using the same method. This analysis provided a basis for verifying whether above- or below-average changes in the different professions in areas of the PRD correlated throughout the PRD.

4 Results

4.1 Results for 2000

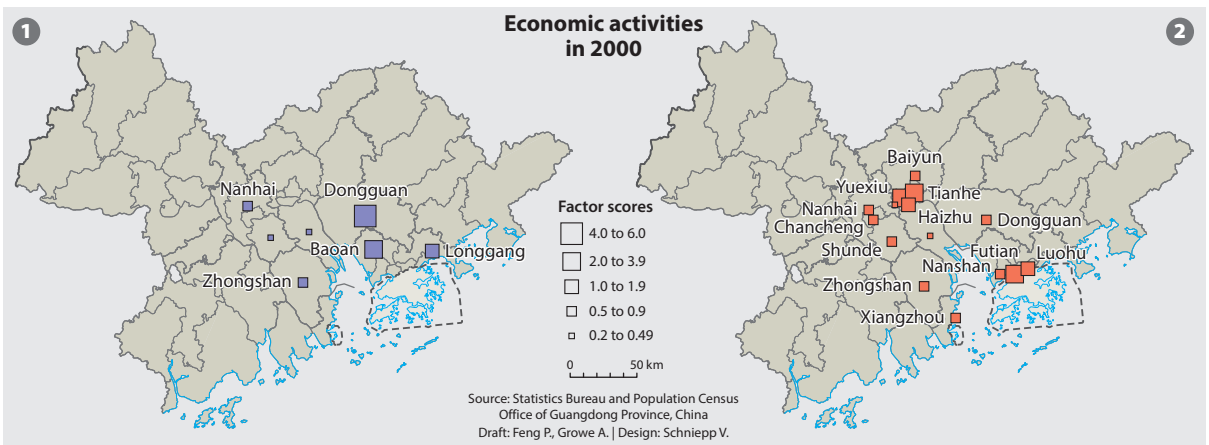
As a first step, a PCA was performed for all professions in 2000. This resulted in two components that explained almost 91% of the variance (Tab. 2). Therefore, in 2000, there were two distinct groups of correlated professions - manufacturing and KIBS (Fig. 2). This was also indicated by the high loadings of the different professions on the extracted components.

The first (manufacturing) component was highly related to all nine blue-collar professions, as well as the four types of general services professions (inspection and measurement personnel, warehouse personnel, purchasing and sales personnel, transport equipment operators). Figure 2a shows the geographical distribution of the positive scores for this component. The geographical pattern mirrors the disparities between the eastern and western PRD. Dongguan (known as a global factory) exhibited the highest score, followed by Bao'an and Longgang, the suburban counties of Shenzhen. Their high values for the manufacturing functions resulted from their spatial closeness to investors from Hong Kong. By comparison, Nanhai and Zhongshan - the western counties of the PRD - also had high scores, but these were relatively much lower. The location of manufacturing professions in these sub-central areas confirmed the process of rural industrialisation in the PRD at the end of the 20th century, when land prices were low and cheap immigrant labour was abundant.

The second (KIBS) component correlated positively with nearly all of the nine KIBS professions. Only administrative office staff had a loading <0.7. The spatial pattern of this component mirrored the distribution of the downtowns in the megacities in the PRD. The core districts of Guangzhou and Shenzhen (Tianhe, Yuexiu, Haizhu, Futian and Luohu) exhibited the highest factor scores.

Tab. 2: Principal components of economic activities in 2000

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	15.750	71.590	71.590	15.750	71.590	71.590	13.017	59.170	59.170
2	4.240	19.272	90.863	4.240	19.272	90.863	6.972	31.692	90.863
3	0.568	2.580	93.443						
4	0.508	2.307	95.750						
5	0.279	1.266	97.016						
6	0.176	0.798	97.814						
7	0.140	0.637	98.451						
8	0.102	0.464	98.915						
9	0.065	0.295	99.210						
10	0.048	0.218	99.428						
11	0.046	0.209	99.637						



1 First Component

Professions	Loading
Machinery manufacturing and processing staff	**0.975**
Electromechanical assembly personnel	**0.974**
Inspection, measurement personnel	**0.971**
Wood, wood-based product personnel	**0.966**
Craft, art production staff	**0.963**
Rubber and plastic products production personnel	**0.962**
Electronic components and equipment manufacturing and related staff	**0.946**
Cutting, sewing and leather product	**0.944**
Warehouse personnel	**0.923**
Textile, knitting and dyeing personnel	**0.899**
Purchasing and selling personnel	**0.844**
Transport equipment operators	**0.842**
Machinery and equipment repair personnel	**0.833**
Administrative office staff	**0.781**
Economic business personnel	**0.679**
Postal and telecommunications business personnel	0.531
Head of business	0.505
Engineers	0.409
Financial staff	0.180
Literary and artistic staff	0.126
Scientific researchers	-0.024
Legal staff	-0.055

2 Second Component

Professions	Loading
Legal staff	**0.959**
Literary and artistic staff	**0.939**
Financial staff	**0.917**
Engineers	**0.862**
Scientific researchers	**0.844**
Postal and telecommunications business personnel	**0.775**
Head of business	**0.751**
Economic business personnel	**0.722**
Administrative office staff	0.523
Purchasing and selling personnel	0.502
Transport equipment operators	0.473
Machinery and equipment repair personnel	0.377
Warehouse personnel	0.338
Wood, wood-based product personnel	0.188
Cutting, sewing and leather product	0.181
Machinery manufacturing and processing staff	0.166
Inspection, measurement personnel	0.148
Electromechanical assembly personnel	0.142
Electronic components and equipment manufacturing and related staff	0.113
Textile, knitting and dyeing personnel	0.113
Rubber and plastic products production personnel	0.103
Craft, art production staff	0.098

Fig. 2: Compositions and spatial patterns of the two components from the PCA of economic activities in 2000

Meanwhile, the second-tier urban downtowns, such as Chancheng and Xiangzhou, and manufacturing counties like Nanhai and Dongguan, also had relatively high scores for the KIBS professions. Unsurprisingly, the central downtowns were the main locations for all the KIBS professions in this polycentric super mega-city region.

Figure 2 provides two kinds of information. Firstly, it shows that two distinct functional patterns of economic activity can be identified in the PRD - manufacturing and KIBS. Secondly, it shows that both functional patterns are located in different spatial units, suggesting a spatial specialisation between manufacturing in sub-central areas and KIBS in central areas in the PRD in 2000.

4.2 Results for the changes in economic specialisation

In order to recognise correlated changed in economic specialisation, a PCA was performed on the CI-values for all functions. Four components (Tab. 3) were extracted, explaining 73% of the variance (Tab. 4). This indicated that the observed professions did not evolve equally in all spatial units.

The first component correlated positively with a positive change in: administrative office staff; electronics components, equipment manufacturing and installation, debugging and maintenance staff; and purchasing and sales personnel (Tab. 3). It also correlated positively with a negative change in: wood and wood-based products personnel; and rubber and plastic products production personnel. The findings indicate that the spatial units highlighted in this pattern gained importance as locations of electronics production and lost importance as locations of low-skilled production activities. Figure 3 shows the locations with factor scores of >0.2 for the respective components. The suburbs of Shenzhen are immediately apparent as the focal points of a positive relative change with respect to electronics products and related activities, such as production, marketing and utilisation. This implies that, between 2000 and 2010, Shenzhen saw an industrial upgrading from the processing of materials to value chains of electronics products and intermediate services. These findings support the argument for functional specialisation. The two-core spatial structure in the PRD contrasts with developments in the hinterlands. Central areas are more likely to experience an upgrading process from relatively simple manufacturing activities to high-skilled manufacturing activities and intermediate services.

The second component strongly correlated with positive relative changes in KIBS professions (with the exception of warehouse personnel), including accountants, lawyers, designers and managers (Tab. 3). The loadings for engineers and scientific researchers were also relatively high. Studies dealing with the spatial patterns of KIBS in mega-city regions have argued that KIBS show a strong tendency to cluster in core areas (Yeh et al. 2017; Zhong and Yan 2008). This argument is supported by our findings from the structural PCA for 2000, which also identified a correlation of KIBS with downtown locations in the large cities. Indeed, activities performed by accountants, lawyers, designers and managers were identified as being located in central areas in 2000. However, the spatial patterns of change differ. Sub-central areas increased in importance as locations for KIBS activities, rather than the central areas, suggesting that accountants, lawyers, designers and managers de-concentrated from the cores of the cities of Guangzhou and Shenzhen, moving to their suburbs, such as Bao'an and Baiyun, or to medium-sized cities or counties, such as Dongguan, Zhongshan and Shunde. This decentralisation process can be understood as a regionalisation process, enriching non-traditional downtown locations in metropolitan regions with metropolitan functions and, thus, introducing a process that overcame the dichotomy between the centre and the hinterland (Growe 2013; Kühn 2001).

The third component had a positive correlation with positive relative changes in activities with regard to finance, but negative relative changes in activities in the fields of clothes-making and electrical machinery assembly (Tab. 3). This suggests a spatial pattern undergoing an economic transformation, from specialising in mass manufacturing to concentrating on strategic services. The third component showed a similar spatial pattern to that of the second component. The spatial units explicitly stressed by this component were the counties of Dongguan, Bao'an and Longgang, and the spatial units slightly emphasised were the urban cores of Guangzhou and Shenzhen in the super mega-city region, such as Futian, Nanshan, Haizhu and Yuexiu. The county of Dongguan is particularly outstanding, with a loading score of 3.8. Considering all three components together, it can be concluded that, in the secondary centres (especially Bao'an) in the PRD, rural industrialisation and an upgrading process of economic activity resulted in a co-location process between high-skilled manufacturing and producer services.

Tab. 3: Composition of the four components of relative change of economic activities between 2000 and 2010

1 First component

Professions	Loading
Administrative office staff	**0.825**
Electronic components and equipment manufacturing and related staff	**0.740**
Purchasing and selling personnel	**0.687**
Engineers	0.553
Transport equipment operators	0.502
lnspection, measurement personnel	0.350
Electromechanical assembly personnel	0.280
Postal and telecommunications business personnel	0.272
Textile, knitting and dyeing personnel	0.224
Scientific researchers	0.182
Economic business personnel	0.134
Machinery and equipment repair personnel	0.028
Financial staff	0.008
Cutting, sewing and leather product	-0.006
Machinery manufacturing and processing staff	-0.009
Legal staff	-0.150
Literary and artistic staff	-0.202
Warehouse personnel	-0.269
Craft, art production staff	-0.491
Head of business	-0.511
Wood, wood-based product personnel	**-0.845**
Rubber and plastic products production personnel	**-0.913**

2 Second component

Professions	Loading
Economic business personnel	**0.923**
Legal staff	**0.830**
Warehouse personnel	**0.808**
Literary and artistic staff	**0.675**
Heaad of business	**0.657**
Scientific researchers	0.584
Engineers	0.583
Postal and telecommunications business personnel	0.406
Financial staff	0.391
Wood, wood-based product personnel	0.318
Administrative office staff	0.261
Rubber and plastic products productionpersonnel	0.256
Transport equipment operators	0.203
Textile, knitting and dyeing personnel	0.157
Machinery and equipment repair personnel	0.137
lnspection, measurement personnel	0.077
Electronic components and equipment manufacturing and related staff	0.042
Purchasing and selling personnel	-0.020
Machinery manufacturing and processing staff	-0.052
Electromechanical assembly personnel	-0.089
Craft, art production staff	-0.247
Cutting, sewing and leather product	-0.373

3 Third component

Professions	Loading
Financial staff	**0.797**
Literary and artistic staff	0.518
Postal and telecommunications business personnel	0.432
Purchasing and selling personnel	0.393
Engineers	0.378
Legal staff	0.318
Head of business	0.268
Wood, wood-based product personnel	0.249
Machinery and equipment repair personnel	0.095
Rubber and plastic products production personnel	0.064
Warehouse personnel	0.035
Transport equipment operators	-0.001
Economic business personnel	-0.004
Electronic components and equipment manufacturing and related staff	-0.088
Scientific researchers	-0.142
Administrative office staff	-0.215
lnspection, measurement personnel	-0.228
Machinery manufacturing and processing staff	-0.288
Cutting, sewing and leather product	-0.290
Craft, art production staff	-0.558
Textile, knitting and dyeing personnel	**-0.796**
Electromechanical assembly personnel	**-0.902**

4 Fourth component

Professions	Loading
Machinery and equipment repair personnel	**0.809**
Inspection, measurement personnel	**0.768**
Machinery manufacturing and processing staff	**0.713**
Transport equipment operators	**0.624**
Purchasing and selling personnel	0.455
Cutting, sewing and leather product	0.348
Warehouse personnel	0.320
Electronic components and equipment manufacturing and related staff	0.281
Engineers	0.252
Wood, wood-based product personnel	0.218
Electromechanical assembly personnel	0.164
Administrative office staff	0.162
Head of business	0.151
Economic business personnel	0.113
Literary and artistic staff	0.088
Textile, knitting and dyeing personnel	0.076
Scientific researchers	0.011
Rubber and plastic products production personnel	-0.075
Craft, art production staff	-0.079
Postal and telecommunications business personnel	-0.095
Legal staff	-0.191
Financial staff	-0.261

The fourth component correlated positively with positive relative changes in activities in machine making, inspecting and repairing, and transportation (Tab. 3). The spatial pattern of this component is complementary to those of the first three components.

Tab. 4: Principal components of relative change of economic activities between 2000 and 2010

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	6.062	27.553	27.553	6.062	27.553	27.553	4.822	21.917	21.917
2	5.413	24.603	52.156	5.413	24.603	52.156	4.616	20.981	42.898
3	2.884	13.111	65.267	2.884	13.111	65.267	3.689	16.767	59.665
4	1.758	7.993	73.260	1.758	7.993	73.260	2.991	13.595	73.260
5	1.511	6.870	80.130						
6	0.994	4.516	84.646						
7	0.663	3.012	87.658						
8	0.619	2.816	90.474						
9	0.468	2.126	92.600						
10	0.402	1.826	94.426						
11	0.338	1.534	95.960						

A comparison of component 4 with components 2 and 3 indicated diverging functional specialisation between the sub-central areas and the wider hinterland. While KIBS functions relatively increased in the sub-central areas, manufacturing activities relatively increased in the regions' hinterlands.

A comparison between component 4 and component 1 suggested that, while manufacturing activities increased beyond the core counties, the graduations in spatial de-concentration differed with regard to different manufacturing functions. Component 1 indicated that the sub-central areas experienced an increase in high-skilled manufacturing, associated with an increase in engineers and administration personnel, while low-skilled manufacturing activities decreased in the respective units. Component 4 highlighted counties where a range of less-skilled manufacturing activities were increasing, including a large share of cutting, sewing and leather production personnel, but also machinery-associated activities. The counties highlighted in this component were hinterland areas, such as Huicheng, Gaoming and Doumen. This suggests a process of spatial transformation in machine- and equipment-related activities from the cores or sub-centres to the hinterland areas in the PRD. This process can be understood as being a further outspreading of rural industrialisation, while, at the same time, the importance of the large cities and city centres was sustained by growing producer service activities (see also YEH et al. 2017).

5 Summarising the spatial and functional patterns of change

The analysis of the relative changes in the majority professions in the PRD revealed four functional patterns that again reflected four distinct spatial patterns. In terms of the composition, two components hinted at positive relative changes in KIBS activities, including accountants, lawyers, designers and managers (component 2) and financial consulting (component 3). The another two components reflected positive relative changes in manufacturing activities and intermediate services, including ICT-manufacturing-related activities, office management and marketing (component 1) and machine and equipment manufacturing, repairing, inspecting and transportation (component 4).

In term of spatial patterns, these four components reflected:

- A sub-central area (component 2);
- The Guangzhou-Dongguan-Shenzhen corridor (component 3);
- Bao'an (component 1); and
- The regions' hinterlands (component 4).

However, to fully understand the changes in the region, it is necessary to also include the identified structural patterns. Figure 4 shows both the spatial patterns from the structural PCA and the patterns of change. Based on this comparison, a spatiofunc-

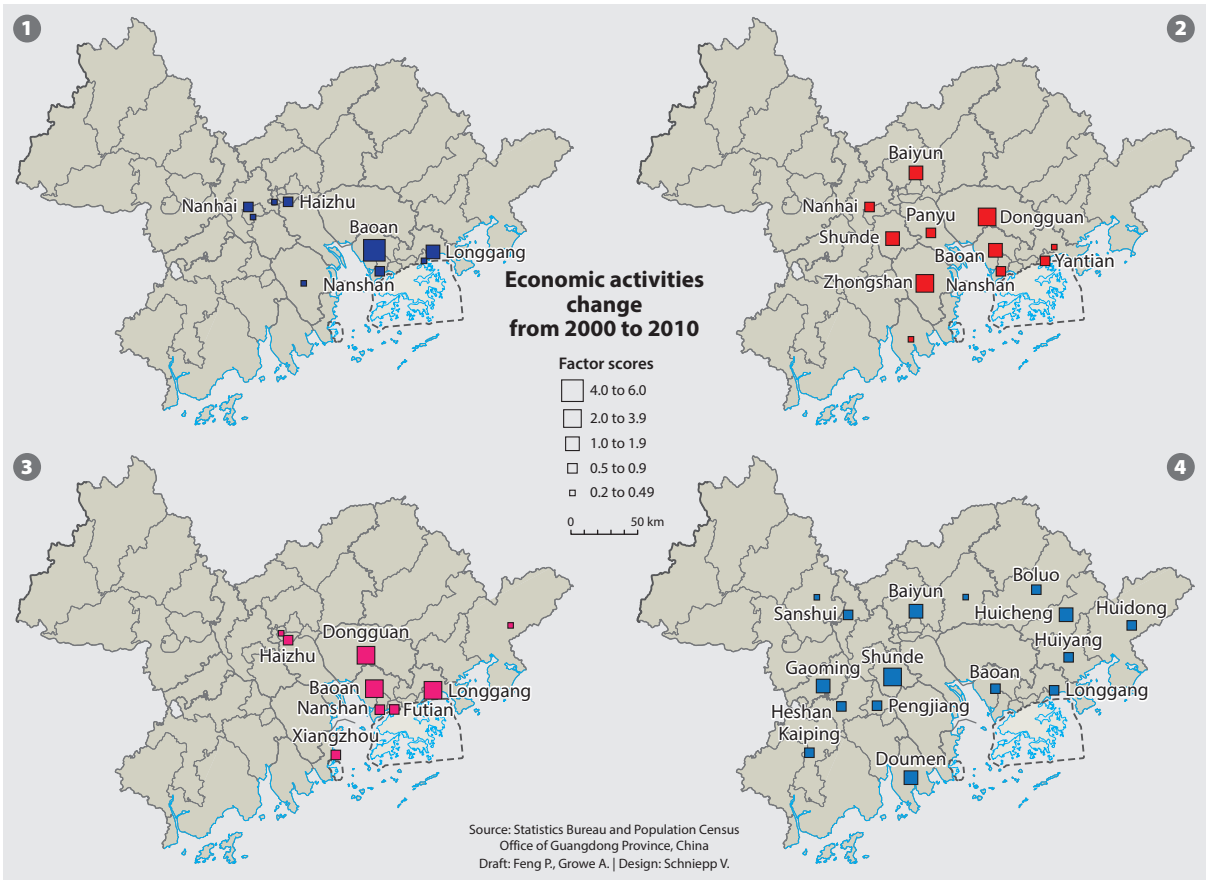


Fig. 3: Spatial patterns of the four components of relative change of economic activities between 2000 and 2010

tional transformation seems to have occurred in certain areas of the PRD. Two main findings were identified.

First, the most remarkable transformation occurred in certain traditional industrial areas that exhibited increasing importance as locations of KIBS activities. For example, Dongguan, the county with the largest score for the manufacturing factor in 2000, showed a significantly positive change in KIBS professions and a significantly negative change in the mass production of clothing and electromechanical products.

Other industrial counties also experienced this kind of transformation, but to a much lesser degree. Differently from Dongguan, these counties, such as Bao'an, Longgang, Nanhai, Zhongshan and Shunde, not only exhibited an increase in importance in the field of KIBS, but also retained positive changes in manufacturing and intermediate activities.

In contrast, with the exception of Nanshan, the central areas, including the core districts of Guangzhou and Shenzhen along with Zhuhai's downtown, showed relatively small increases in KIBS activities (with a relatively positive increase mainly in finance). This can be considered to be the result of functional saturation in these developed areas. Further increase is possible, but also restricted by limited land and high prices for office space.

Second, some hinterland areas became new manufacturing sites during the period to 2010, compared with the spatial pattern of such functions in 2000. Compared to land prices in the core or subcentral areas, the lower land prices in the hinterland appealed to industries in pursuit of low production costs for their branch factories. For example, manufacturing firms in Shenzhen tended to set up affiliated assembly factories in counties in Huizhou, while retaining their headquarters and marketing departments in Shenzhen.

6 Conclusion and discussion

The aim of this paper was to evaluate the assumption that economic catching-up processes in super mega-city regions lead to a decentralisation

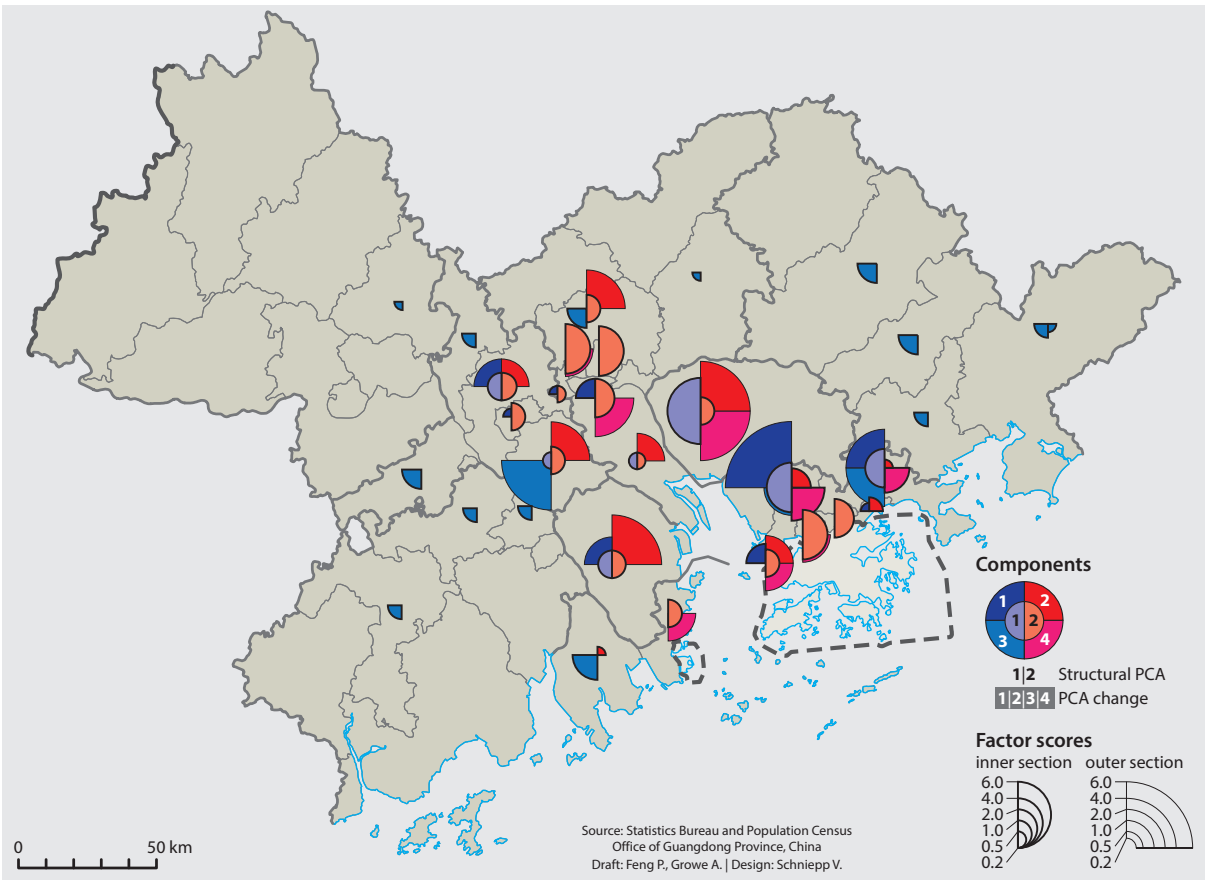


Fig. 4: Structural patterns in 2000, and change between 2000 and 2010 (Source: own calculations)

of economic functions within the region, while, at the same time, a change in locations of economic functions can be observed, leading to new forms of functional specialisation between the multiple cores and the hinterland within the region.

By using PCA, both questions concerning changing patterns could be addressed. Changing spatial patterns leading to increased intraurban and regional polycentricity were identified. Also, changing functional patterns leading to the decentralisation of manufacturing activities, alongside central locations gaining importance as service hubs, could be detected.

The first question dealt with changing patterns of importance in polycentric super mega-city regions. We observed increasing intraurban polycentricity in the cities of Foshan, Guangzhou and Shenzhen through an increasing importance in KIBS and in manufacturing activities, in different sub-city districts, while, at the same time, changes in the cities of Huizhou, Zhaoqing and Jiangmen indicated decentralisation processes relating to manufacturing activities.

The second question dealt with changing functional patterns in polycentric super mega-city regions. We observed a change from manufacturing to KIBS activities in the inner cities – namely, Foshan, Guangzhou and Shenzhen – while, at the same time, the hinterland cities of Huizhou, Zhaoqing and Jiangmen experienced an increase in manufacturing activities.

The replacement of manufacturing activities from central locations to hinterland cities, however, does not indicate a loss of the economic importance of the central locations. Yeh et al. (2017) showed that the increase in rural industrialisation in the PRD had not reduced the importance of large cities. Based on green-field foreign direct investment data, Schiller et al. (2015) identified a functional upgrading of Guangzhou and Shenzhen, from manufacturing activities to services. The process of economic transformation (including the manufacturing upgrade and servitisation) in the sub-central areas contributed to sustained development in the region. As a result, the economic spatial structure of the PRD tends to be more polycentric.

However, open questions, with regard to developments in polycentric super mega-city regions in China, remain. First, the period the data covers should be extended to more recent years, to incorporate data from the Chinese census of 2020, which will be published in the next few years. The data used herein (i.e. changes that occurred between 2000 and 2010) cover the initial phase of China opening up the service market after its accession to the World Trade Organisation in 2001 and the 10th Five-Year Plan (2001–2005), and included an initial policy of externalising markets for the service sector (Yeh and Chen 2020). However, the last decade (i.e. from 2010 until 2020) still experienced an extraordinary growth in Chinese super mega-city regions.

After this first phase of growing service activities, further studies should analyse the increasing and differentiating service patterns with regard to the functional logic of the knowledge economy. Further studies could differ spatial patterns, according to KIBS based on analytical knowledge, KIBS based on synthetic knowledge, and KIBS based on symbolic knowledge (Growe 2013).

With regard to databases, future analyses could examine changing patterns based on relational data. Relational data provides much more direct insights into changing relations within regions. Based on the current dynamics of polycentral super mega-city regions, it is certain that a number of future studies will be necessary to really obtain an understanding of changes in these vital settings.

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