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The Middle-aged and Knowledge Workers: Demographic and Economic Changes in the Pearl River Delta, China

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Abstract: Demographic and economic development can be seen as two sides of one coin in the process of regional development. This article deals with how economic and demographic changes influence the settlement structure and development of the Pearl River Delta (PRD) and lead to regionalization processes within the large agglomerations. The aim of the study was to understand the interrelation between the three aspects: economic change, demographic change and change of spatial structures. Based on population age and occupational data, spatial changes in demographic structure and economic activities from 2000 to 2010 were analyzed. It was found that the demographic and economic change reflected changing spatial patterns between the urban centers and the hinterland in the PRD. Two processes were apparent during the studied period in the hinterlands and the high-density areas of the PRD. On one hand, the hinterlands in the PRD attracted more manufacturing activities, while the inner high-density areas experienced a decrease in manufacturing, associated with an increase in young labor in regions where workplaces that only required limited education expanded. On the other hand, specialization in knowledge-intensive business services increased in the inner high-density areas, which also saw an increased share in the older population. This finding suggests that increasing knowledge-intensive work correlates with higher age structures due to the longer formal education required and also the benefits knowledge workers accrue through experience and gained knowledge over time. Therefore, based on a transformation process, we tentatively conclude that the populations in high-density areas in the PRD became more middle-aged and were represented by more knowledge workers.

Keywords: manufacturing; knowledge-intensive business services (KIBS); economic change; demographic change; Pearl River Delta

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1 Introduction

In the past four decades, strong socioeconomic changes have been happening in China, particularly in the country's large agglomerations. In the first two decades of the 21st century, China's economic output continued to grow by an average of 9% per year (National Bureau of Statistics of China, 2020). This is due to a change in the orientation of the economy, such as the opening of the economy to globalized economic processes (Yeh and Chen, 2020) and a reorientation of economic activities towards services and knowledge-intensive activities (Yang et al., 2018; Hu et al., 2019). During this period, the long-term consequences of population policy decisions from the 1980s have become visible. A collective aging of the population is apparent, and has led to demographic changes across the country. Demographic and economic changes are particularly apparent in areas

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of large agglomerations. The advantages of agglomeration in large centers and the opening up of the national economy has led to a particular dynamic, manifested by the emergence of so-called super-megacity regions. In these areas, the growth of several large cities with over 10 million inhabitants has led to multi-core agglomeration regions, including both high-density, large core cities and less dense spaces.

The paper deals with how economic and demographic changes influence the settlement structure and development of agglomerations and lead to regionalization processes within the agglomerations. While in many studies, the influence of economic and demographic changes on spatial structures are addressed individually, we refer to the concept of regional urbanization (Soja, 2013), addressing both changes and their influence on changing spatial structures in large agglomerations.

The economic integration into globalized economic processes, and a structural change towards a more services-oriented economy, has led to changing processes in the core cities, with increasingly knowledge-intensive industrial and service jobs displacing the simpler industrial and service jobs that were previously prevalent. Changes have also been reported in the hinterlands and the spaces between the major core cities. These findings have already been documented in several studies. The connection between the demographic and economic changes in the large agglomeration areas, however, has not yet been systematically examined.

The population development of large, and growing, agglomeration areas is not determined solely from the number of births. The current two-child policy has not led to the currently observed population growth in these large agglomerations. Instead, the changes in population have resulted from migration processes into the large centers. Against this background, the question arises as to what extent the population and age structure were changing in the core cities, the spaces between the cities and in the hinterland, and how these changes related to the structural changes occurring in the large agglomerations.

Three regions, Beijing-Tianjin-Hebei (BTH), the Yangtze River Delta (YRD) and the Pearl River Delta (PRD), represent the largest super-megacity areas in China. Of these three regions, the PRD is the most polycentric. This study analyzed questions of economic and demographic structural change in the settlement system of Chinese supermegacity areas, by taking the PRD as an example. To achieve the research goal, this study used principal component analyses (PCA) and location quotients (LQs), based on population census data.

2 Literature Review: Processes of Socioeconomic Change in Rising Megacity Regions in China

2.1 Increasing integration in the knowledge economy and economic change

With the Chinese policy of opening up (Zhang, 2003), the increasing interdependence of global economic relations is leading to the globalization of Chinese companies. In the first phase of opening up, industrial production companies benefited in particular. During this phase, Chinese companies were referred to as the 'workbenches of the world' (Schiller et al., 2015). However, this situation has changed significantly over the past two decades (Yeh and Chen, 2020). As in other countries (e.g., England, France), large cities and the surrounding agglomeration areas are also at the center of economic activity in China. Duranton and Puga (2005) posited that manufacturing companies could easily be relocated to small towns and, due to lower land rents, to their surrounding regions. In contrast, the management functions in the core cities remain agglomerated.

This division is influenced by the difference in importance of transport costs and spatial requirements between the manufacturing industry and the service sector (Feng et al., 2020). Accordingly, a reduction in transport costs would lead to a different choice of location for manufacturing companies than for service providers; transport costs are more important to manufacturers of industrial or commercial products than to service providers. Nevertheless, there are also costs for service providers in economic processes. Production from these non-material services is based on complex interactions (Sharmeen et al., 2014; Growe, 2019a). Dense agglomerations facilitate personal interaction (Boschma, 2005; Torre and Rallet, 2005; Boschma and Iammarino, 2009), as well as the organization of business activities via information and communication technologies and meetings in physical colocation (Denstadli and Gripsrud, 2010; Torre, 2015; Grabher et al., 2018). In addition, there is a critical mass of potential interaction partners and the infrastructure to enable personal meet-

ings, such as airports or trade fairs (McNeill, 2009; Growe, 2019b).

With regard to the spatial requirements, service activities, especially knowledge-intensive business services (KIBS), are carried out in offices, and are therefore less space-consuming than manufacturing activities (Feng et al., 2020). Manufacturing activities, on the other hand, are carried out in factories or commercial sites that require more space for production facilities, logistics and transport infrastructure. Central locations with high property prices are therefore less attractive (Feng et al., 2020). Lower property prices and transport routes with less traffic than in central locations are more important. As a result, economic catch-up processes at core locations can lead to a relocation of manufacturing activities to extra-core locations, while less space-consuming and high-income activities increase at central locations (Schiller et al., 2015).

2.2 Aging and demographic change

After the one-child policy was introduced in China in 1980, a process of collective aging was observed in the country at the end of the 20th century. The median age increased from 21.9 yr in 1980 to 36.5 yr in 2015. Because of the low birth rate, a rejuvenation of the population in an area will result primarily from migration movements. Areas of migration are primarily economically strong, providing good earning potential; however, there are restrictions in China regarding long-term and legal migration due to the *hukou* system (Chinese citizens are given a *hukou* at birth, of which there are two forms , that are rural and urban *hukou*.) (Pahl, 2016). As a reaction to the restrictive effects of the *hukou* system, on migration on one hand and the prosperous economic centers with high labor requirements on the other hand, migration controls have been gradually relaxed since the mid-1980s. In 1985, migrants from rural areas were able to obtain a temporary residence permit that allowed them to work and live in the city. Highly-qualified people in particular have been able to receive new forms of urban *hukou* from some city councils since the late 1980s (Liu et al., 2014).

With regard to different occupational groups, however, there were still strict restrictions on obtaining an urban *hukou*. Liu and Xu (2017) pointed out that the recent commercialization of the *hukou* status has led to an increased concentration in highly-skilled migrants in wealthy agglomerations. Low-skilled migrants in particular can rarely afford to move to the wealthier megacity regions. Migration patterns are also influenced through economic spatial patterns. Because of the different spatial patterns that derive from different economic functions, well-educated migrants have been observed to be spatially more concentrated than less-educated migrants are, as labor-intensive industries are spatially more dispersed, whereas knowledge-based activities are rather concentrated in agglomerations and their cores (Liu et al., 2014).

However, apart from occupation, age also influences migration patterns (Zhang et al., 2020). Analyses of age-specific migration have shown that younger adults are especially more mobile. This is explained by a higher sensitivity of this age group to different employment opportunities in various regions, compared with older population groups (Liu et al., 2014). Liu et al. (2014) reported that the massive migration to the east, induced by the unbalanced economic development in China as a whole, and made possible by the relaxation of migration restrictions, continued into the 2000s. As the first province to introduce economic reforms, Guangdong was one of the most important migration destinations in China.

2.3 Regional urbanization processes and megacity regions

In analyzing Chinese urbanization processes and economic development, megacities and their different spatial units have recently come into focus. Along the Chinese coast, considerable economic development has led to so-called ‘super mega-city regions’ (Yeh and Chen, 2020), which consist of several large centers and their hinterlands. The dimensions of these spatial configurations are extraordinary, and further research is needed especially into the relationships between the centers and the hinterlands.

Traditionally dominated by one or two centers, the transition through urbanization, the market economy and globalization has led to more polycentric city patterns in the Chinese megacity regions, as a result of creating new cities and enlarging existing ones in the hinterlands of the major centers. This emergence of new cities was partly driven by the development of a rural transformation (Lin, 2002; Yeh and Chen, 2020). A large number of low-income households whose mem-

bers work in the cores of Guangzhou are forced to live in the suburbs due to the high cost of living in those core areas (Liu and Hou, 2016). While the peri-urban zone in the PRD was initially less developed, after a decade of development, this zone has become the region's main destination for immigrants and foreign investment (Lin, 2001a). The process of agricultural diversification and the industrialization of rural areas has also resulted in a shift in the focus of economic development and urbanization from the central cities of the large agglomeration areas to zones outside and between the large core cities in the PRD (Lin, 2001b).

Soja (2013) argued that the increase in population in the surrounding areas of large core cities indicates a process of regional urbanization. This process means that the previously distinct differences between the urban centers and their clearly-delimited rural surroundings are evening out. For example, so-called 'edge cities' (Garreau, 1992) make the surrounding suburban area more urban (Knapp and Volgmann, 2011; Münter and Volgmann, 2014).

The process of regional urbanization is not only characterized by an increase in population numbers in the surrounding area. The increase in economic functions, such as an increase in jobs in the surrounding area, is an important criterion for this change (Feng et al., 2020; Wagner and Growe, 2020a). At its core, the process of regional urbanization emphasizes that the increasing importance of cities as places to live and work in the knowledge economy is closely related. The need to constantly acquire new knowledge in work processes also influences private life and the choice of location (Florida, 2006, 2008). The search for suggestions and inspiration takes place not only during working hours (Growe and Mager, 2018; Wagner and Growe, 2020b), but also in leisure time, in the evenings and on weekends. Consumption opportunities and opportunities for recreational activities and cultural use are significantly more extensive and differentiated in large cities than in small towns and in rural areas (Pratt, 2012; Brown, 2015).

Thus, in our hypothesis, we assume a connection between economic change and demographic change against the backdrop of regional urbanization processes in megacity regions. We expect an increase in young labor (older youths or very young adults) in parts of megacity regions where workplaces that do not require a long education increase, such as labor-intensive industrial work. We also expect an increase in young and middle-aged adults in regions where more knowledge-intensive work is located, which requires a more extended education or work experience. To examine these assumptions, this study aimed to answer two questions: 1) how did the different parts of the PRD megacity region develop and change their importance in terms of their becoming a location for various demographic and economic groups; and 2) how have the relationships between the different spatial parts of the PRD megacity region changed?

3 Materials and Methods

3.1 Data

To analyze the demographic change and its connection to economic change in the PRD, we used population census data released by the government of Guangdong Province, China, which conducts censuses every 10 yr, collecting basic information about age, gender, *etc*. in short-table surveys, and detailed information, such as marriage status, occupation and living conditions, in long-table surveys. To save time and costs, only 10% of households in each residential community are chosen, randomly, by the surveyors to fill in the long-table surveys (Guangdong Provincial Bureau of Statistics Office for the Population Census of Guangdong, China, 2002; 2012).

Two datasets, from 2000 and 2010, were used to enable a comparison over time. These are the latest population census datasets to be released by the government, as the results of the 2020 census might not be released. The data were provided at the county level—the smallest spatial unit available—for both occupation and age information. The delimitation of the counties can meet the need to differentiate the urban cores from their hinterlands, which fits our analysis of economic specialization in megacity regions. Given that parts of the borders of some counties in the PRD were redefined during the 10-year period under examination, we made relevant adjustments in order to make a direct comparison of the spatial patterns between 2000 and 2010 possible (Feng et al., 2020).

Two features of the residents—age and profession—were exported from the datasets provided by the Guangdong Provincial Bureau of Statistics Office for the Population Census, China. (Guangdong Provincial Bureau

of Statistics Office for the Population Census of Guangdong, China, 2002; 2012)

3.1.1 Population age data

The aggregated numbers of residents in different age groups were extracted from all the permanent residents in the PRD. The original data concerning the age ranges were collected for 5-year intervals. As those aged at 15 were integrated in 15–24 age group, those aged 0–14 and above 60 yr were viewed as non-working people, based on the consideration that only people aged between 16 and 59 yr are classed as legal labor in China, and have a high rate of employment (Banister et al., 2012). For the aggregation of Chinese interprovince migration at the working age, Liu et al. (2014) divided them into five groups, that are those aged 15–19, 20–24, 25–29, 30–44, and 45–59. Non-immigrant residents were also incorporated in our analysis. To simplify the analysis, the working residents aged 15–44 in our analysis were aggregated into 10-year intervals, which was verified as being feasible for detecting a change in age structure (Banister et al., 2012). In our analysis, those aged 15–24 were in their first job or receiving higher education; those aged 25–34 were in the early stages of their career and starting a family. Those aged 35–44 worked at rearing family members, including children and retirees in their household. The 45–59 group were the same as that used by Liu et al. (2014). Therefore, we aggregated all residents into six age groups: 0–14, 15–24, 25–34, 35–44, 45–59 and 60 and above.

3.1.2 Employment data

The aggregated numbers of employees in different professions were collected according to the official occupational codes for 1999 (GB/T 6565−1999, Chinese Standardization Administration), and included careers in manufacturing and the services. Using this data, the employee numbers were estimated in terms of each type of profession, rather than using businesses classified by sector (for a sectoral analysis, Wang et al. (2016) and Yeh et al. (2017)). The cross-border investment projects of international corporations were viewed through the lens of the functional division of labor between regions or nations on the basis of business activity (Burger et al., 2013; Schiller et al., 2015). However, this approach excludes domestic activities and might lead to a partial picture of functional specialization in space (Schiller et al., 2015), as domestic firms are becoming essential players in regional development in the new millennium (Wang et al., 2016). Viewing functional urban research through the lens of profession (as conducted, for example, by Brunelle (2013) and Growe (2016)), we argue that occupational data can provide for a better analysis of functional divisions in the PRD.

The classification of occupations was shown in Table 1. The employee groups providing services were distinguished between KIBS and goods-related services (Bryson et al., 2008; Growe, 2016). Those employees producing physical products were classified into high-tech, medium-tech and low-tech categories, based on the classification standard of the National Bureau of Statistics of China (2010) and the Eurostat (https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:High-tech_classification_of_manufacturing_industries).

Table 1 Classification of occupations

Profession	Code	Type
Head of business (managers)	B2	KIBS
Scientific researchers	B3	KIBS
Engineers	B4	KIBS
Economic business personnel	B6	KIBS
Financial staff	B7	KIBS
Legal staff	B8	KIBS
Literary and artistic staff	B9	KIBS
Administrative office staff	B12	KIBS
Postal and telecommunications business personnel	B13	Goods-related services
Purchasing and selling personnel	B15	Goods-related services
Warehouse personnel	B16	Goods-related services
Machinery manufacturing and processing staff	B22	Medium-tech
Electromechanical assembly personnel	B23	Medium-tech
Machinery and equipment repair personnel	B24	Medium-tech
Electronic components and equipment manufacturing, installation, debugging and maintaing staff	B26	High-tech
Rubber and plastic products production personnel	B27	Medium-tech
Textile, knitting and dyeing personnel	B28	Low-tech
Cutting, sewing and leather products	B29	Low-tech
Wood, wood-based product personnel	B33	Low-tech
Crafts, art production staff	B38	Low-tech
Transport equipment operators	B41	Goods-related services
Inspection, measurement personnel	B43	Goods-related services

3.2 Research area

The PRD is one of the four super-megacity regions in China (Yeh and Chen, 2020). Its territory covers 42 200 km^2, and includes nine cities at or above prefectural level and 45 counties. In 2010, 56.1 million people lived there, 30.9% more than the figure for 2000. The demographic distribution was highly agglomerated. The central districts in Guangzhou and Shenzhen, the two megacities in the PRD, had population densities of over 10 000 per km^2, and the total populations of both megacities exceeded 10 million people in 2010. Although both Dongguan and Foshan had relatively lower population densities, they had also developed into large cities, each exceeding 5 million residents. In contrast, the peripheral counties were much less appealing to residents, both the *hukou* and floating populations, and were peppered by small towns with rural characteristics, except for a few urban central units.

For illustrative purposes, Yeh and Chen (2020) divide the PRD into central areas (downtown of the core city), sub-central areas (suburbs of the core city and the downtowns of other large/medium cities), and inner and outer hinterlands.

Based on their work (Yeh and Chen, 2020), and combined with population density (Feng et al, 2020), we classified the counties of the PRD into five types of areas (Fig. 1):

(1) Megacity cores, with population densities >10 000 per km^2;

(2) Inner high-density districts, urban areas with population densities > 2500 per km^2;

(3) Outer high-density districts, urban areas with population densities > 1000 per km^2;

(4) Inner hinterlands, rural counties with population densities > 500 per km^2;

(5) Outer hinterlands, rural counties with population densities < 500 per km^2.

Overall, the various levels of settlement in the PRD may have had an influence on the differentiation between, and shift in, demographic age structures and economic functions among the counties in the PRD.

3.3 Analytical methods

In order to address the two research questions posed in Section 2, principal component analyses (PCA) and location quotients (LQs) were applied in order to analyze the data. PCA was used to explore resident age structure and spatial features at the county scale, while LQ was used to detect the degree of concentration into five categories of land in the PRD, with regard to resident age composition and career, respectively.

3.3.1 Identifying changes in importance through principal component analyses

By focusing on relative changes, this study aimed to shed light on how various working and non-working people shifted among the cities and rural areas in the city system of the PRD. Following Growe (2016), PCA was applied to explore correlations between the gains and losses in different age groups' shares of all the counties in the PRD. PCA has been verified as a technique for detecting spatial patterns of similar development in economic activities by reducing multiple indicators to a few components (Taylor and Walker, 2001; Taylor et al., 2014; Growe, 2016; Feng et al., 2020). We extended the application of this method to structures of the six age groups mentioned above.

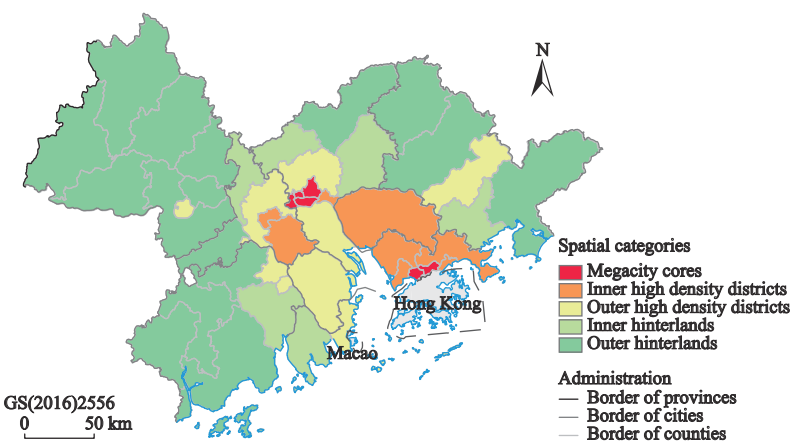

Fig. 1 County types in the Pearl River Delta (PRD)

The first step was to calculate the share of each age group in every county in the PRD, with regard to all residents in the spatial unit, in 2000 and 2010, respectively. The second step was to compute the percent change of all the six age groups' share in each county between 2000 and 2010. In the third step, the changes were *z*-standardized, resulting in values that measured whether the change in one age group's importance in a spatial unit, as a location for working or not-working, was above or below average in the PRD. This *z*-standardized value was termed the 'change in importance' (*CI*), as used by Growe (2016), and therefore each of the 45 counties had six *CI* values calculated.

The average of the *CI*-values was 0, with standard deviations of 1 and –1. The z-standardized *CI* can therefore be interpreted as follows (Growe, 2016):

(1) *CI*-values of between –1 and 1 denote a small change;

(2) *CI*-values of between –2 and –1 or between 1 and 2 denote a medium-sized change; and

(3) *CI*-values of > 2 or < –2 denote exceptional change, in statistical terms.

Based on these *CI*-values, one dynamic PCA was performed. Before using this dynamic PCA, a structural PCA (based on the percentage of one age group in each county in 2000) was applied, using the same method, to provide help in decoding the results of the dynamic analysis. This analysis provided reference information for verifying whether above- or below-average changes in the different age groups were spatially correlated throughout the PRD at the county spatial scale.

3.3.2 Identifying above-average spatial locations of different groups through location quotients

The *LQ* is a way of discovering the industries, occupations or demographic groups that are concentrated in a regional economy, with regard to average level in a larger reference region. In this analysis, it was used to reveal which general characteristic or asset in each sub-region (Fig. 1) were unique in comparison to the whole PRD. To be specific, the *LQ* is a ratio that compares a category of area (e.g., megacity cores) to the PRD based on one age group (e.g., 15–24) or career (e.g., KIBS activities) of the residents.

The *LQ* can be computed using the equation $(X/Y) / (X'/Y')$, where X is the number of those in one age group or undertaking one economic function in one type of sub-region, and Y is the total number of population or employees in this sub-region, with X' and Y' being similar datapoints for the PRD. Therefore, the *LQ* value indicates the relative concentration of the two assets in one category area compared to the PRD. A *LQ* value >1 means an above-average concentration of age groups or economic functions in the spatial category, while values < 1 represent a below-average concentration of age groups or economic functions. In our analysis, a *LQ* was first computed on the data from 2000 and then another was calculated for the data from 2010. The change in *LQ* value from 2000 to 2010 was calculated by simple subtraction of these two *LQ*s.

4 Demographic and Economic Changes in the Pearl River Delta

4.1 Age structure in the Pearl River Delta

As a result of the aging population resulting from the one-child policy that has been strictly enforced since the 1980s in China, both the PRD and China have experienced a decreasing share in people aged under 14 years, but an increasing share of retirees in the first decade of the 21st century. The degree to which this has affected the PRD is fairly insignificant, it being one of the most developed areas and, as such, appealing to floating immigrants. In general, the PRD saw less of a decrease in the share of youths and less of an increase in the share of senior people than China in general.

However, the structure of those of working age in the PRD transformed greatly over the 10 years. While the percentage of those aged 15–24 in the whole China increased slightly, the figure for the PRD dropped steeply, by 5%. In contrast, the share of middle-aged people (35–44) rose much more significantly in the PRD, by 6.66%—twice the general level in China. This implies that the change in age structure in the PRD from 2000 to 2010 might be unique in China (Fig. 2).

To understand the specific features of the demographic structure among the six age groups in the PRD, the spatial patterns at the starting point in 2000 are described based on structural PCA analysis in Subsection 4.1.1, and then Subsection 4.1.2 provides an analysis of the dynamic change in the age structure in the PRD.

4.1.1 Spatial patterns of age structure in the Pearl River Delta in 2000

As a first step, a structural PCA was performed for percentages of each age group in each county in 2000. This

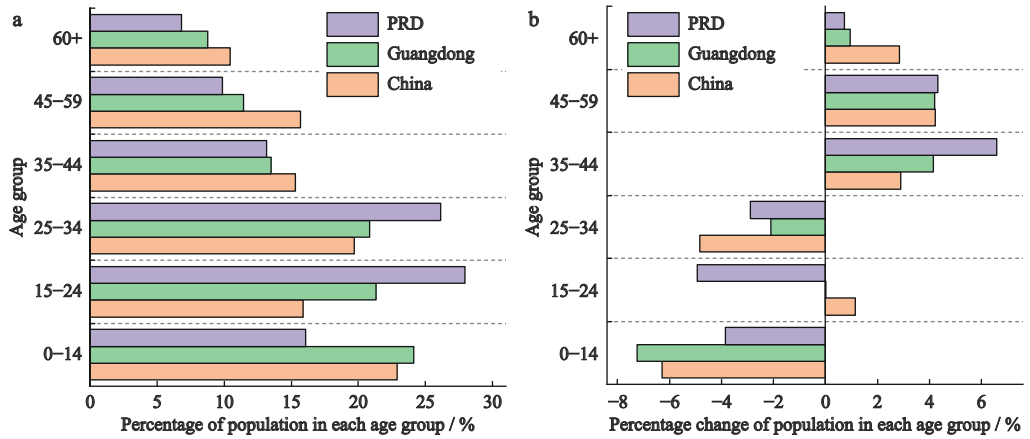

Fig. 2 Age structure in 2000 (a) and age structure change (b) between 2000 and 2010 for the Pearl River Delta (PRD), Guangdong and China

resulted in two components that explained almost 95% of the variance (Table 2). Therefore, in 2000, there were two distinct types of correlated age groups—non-working and working groups (Fig. 3). This was also indicated by the high loadings of the different age groups on the extracted components (Table 3).

The first component was highly positively related to the groups aged under 14 and above 60, and negatively related to those aged between 15 and 34 (Table 3). Therefore, this can be identified as a non-working-group component. Fig. 3a shows the geographical distribution of the positive scores for this component. This geographical pattern is in line with the spatial distribution of the hinterlands of the PRD. Most suburban counties in the peripheral cities (such as Zhaoqing, Jiangmen and Huizhou) in the hinterlands have high scores for this component. Meanwhile, the counties on the outskirts, such as Zengcheng and Conghua in Guangzhou City, and Doumen in Zhuhai City, also exhibit positive values, to different extents. In contrast, the urban centers of

Table 2 Principal components of the age structure in 2000 in the Pearl River Delta

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	Percentage of variance / %	Cumulative / %	Total	Percentage of variance /%	Cumulative / %	Total	Percentage of variance / %	Cumulative/ %
1	4.684	78.067	78.067	4.684	78.067	78.067	3.269	54.484	54.484
2	1.016	16.926	94.993	1.016	16.926	94.993	2.431	40.509	94.993
3	0.215	3.576	98.569						
4	0.067	1.121	99.69						
5	0.019	0.31	100						

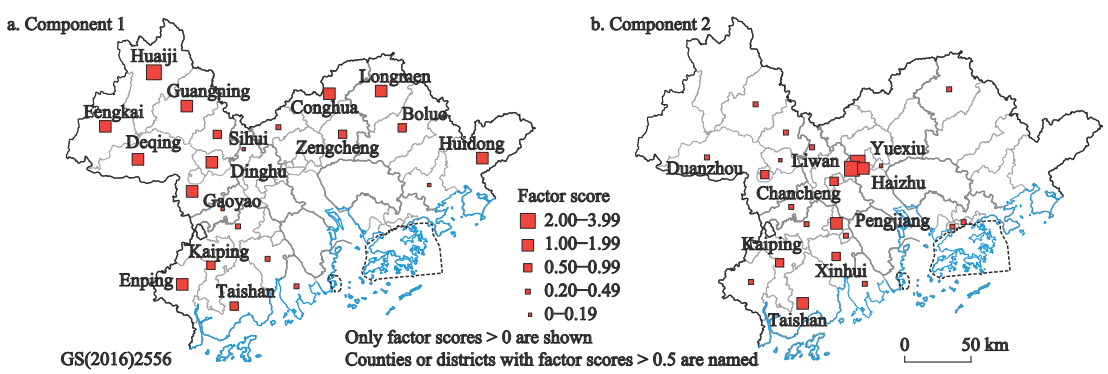

Fig. 3 Factor scores for age structure in 2000 in the Pearl River Delta

Table 3 Loadings of components for age structure in 2000 in the Pearl River Delta

Age stage	Component 1	Age stage	Component 2
0–14	**0.975**	**35–44**	**0.978**
60+	**0.723**	**45–59**	**0.754**
45–59	0.616	60+	0.649
35–44	0.057	0–14	0.018
15–24	**–0.764**	25–34	–0.351
25–34	**–0.911**	15–24	–0.600

the peripheral cities and most of the counties in the megacity centers and high-density areas do not have positive values.

The second component, identified as the working-groups component, correlated positively with residents aged 35–59 (Table 3). The senior group is also highly related to this component, but to a lesser extent. The biggest scores for this factor were located in Guangzhou city's central areas (Fig. 3b). Although Shenzhen, another megacity in the PRD, only started to develop from a village by absorbing immigration when China's reform and opening-up policy was released in 1978, its downtown districts also show positive scores for this component. In addition, central urban districts in cities like Zhaoqing, Foshan and Jiangmen also exhibit relatively high scores, compared to the smaller scores reported for the hinterlands. In general, the urban centers stand out in terms of the second component.

Based on the results of the two PCAs, we argue that there was a clear duality of population age composition between the peripheral and central areas, both inside the cities and in the whole PRD region, in 2000.

4.1.2 Changing spatial patterns of age structure in the Pearl River Delta between 2000 and 2010

In order to recognize a correlation-in-change trend among the six age groups, a PCA was performed on the *CI* values for all counties in the PRD. Three components were extracted, explaining 88% of the variance (Table 4). This indicates that the observed age structures did not change equally in all spatial units.

The first component has a positive relation with the percentage change in people aged under 14 and those aged between 35 and 44, but a negative relation with the change in citizens aged 15–24 (Table 5). The findings indicate that the spatial units that stood out in this component gained importance as places where established middle-aged couples lived with their children rather than as places appealing to young people preparing for, or in the very early stages of, their careers. Fig. 4a shows the locations with factor scores of > 0 for this component.

The highest scores (>1.5) are concentrated in the out-

Table 4 Principal components of the changing age structure from 2000 to 2010 in the Pearl River Delta

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	Percentage of variance / %	Cumulative / %	Total	Percentage of variance / %	Cumulative /%	Total	Percentage of variance / %	Cumulative / %
1	2.678	44.626	44.626	2.678	44.626	44.626	2.581	43.015	43.015
2	1.72	28.666	73.292	1.72	28.666	73.292	1.481	24.689	67.704
3	0.879	14.655	87.947	0.879	14.655	87.947	1.215	20.243	87.947
4	0.393	6.544	94.491						
5	0.331	5.509	100						

Table 5 Loadings of components for age structure change from 2000 to 2010 in the Pearl River Delta

Age stage	Component 1	Age stage	Component 2	Age stage	Component 3
0–14	**0.891**	**60+**	**0.829**	**45–59**	**0.937**
35–44	**0.815**	45–59	0.188	60+	0.312
45–59	0.11	0–14	0.17	0–14	0.176
60+	–0.211	35–44	0.027	25–34	0.023
25–34	–0.375	15–24	0.024	15–24	–0.179
15–24	**–0.961**	**25–34**	**–0.854**	35–44	–0.42

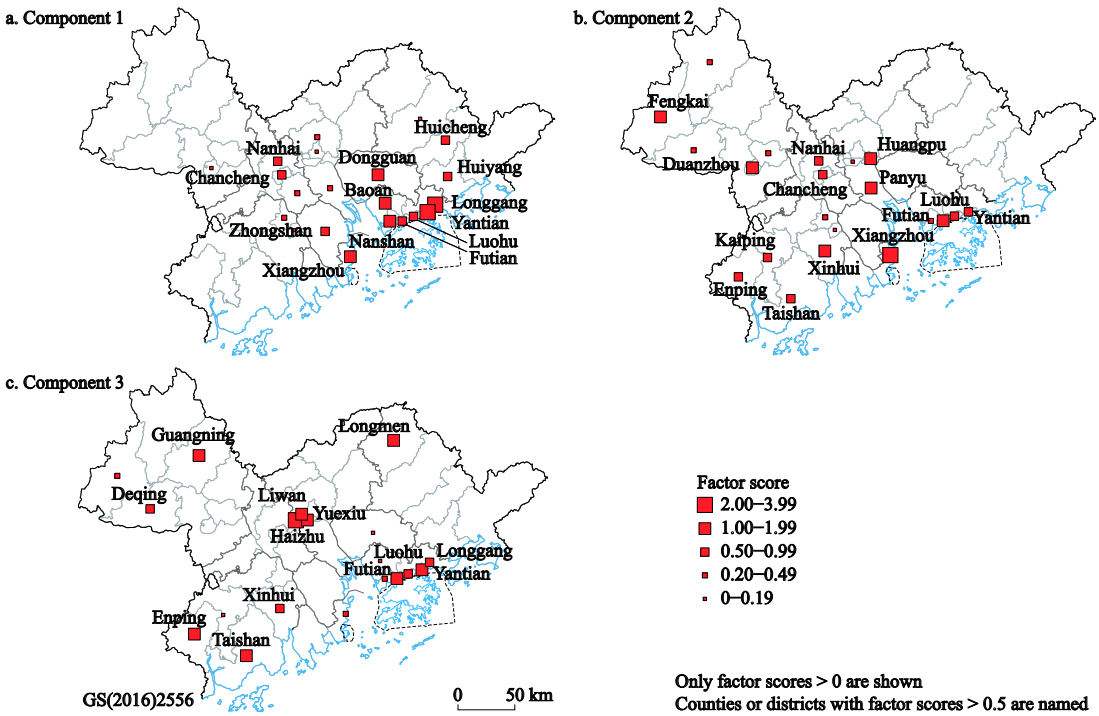

Fig. 4 Factor scores for the change in age structure from 2000 to 2010 in the Pearl River Delta

er downtown (Nanshan and Yantian) and suburban (Bao'an and Longgang) districts of Shenzhen City, and Dongguan City. In addition, other places in high-density areas, such as Zhuhai City center (Xiangzhou), Zhongshan City, Foshan City center districts (Chancheng and Nanhai) and Huizhou City center (Huicheng), show relatively high scores for this component. In general, most of these places with high scores for the first factor are in high-density areas and urban centers. This implies that shares of young, cheap labor in counties from central areas decreased over the 10 years, while shares in those shouldered with rearing responsibilities increased in the PRD. The situation in the hinterlands was the opposite.

The second component positively correlated with an increase in the retirees' share, and negatively correlated with the percentage change in residents aged between 25 and 34 (Table 5). This component was identified as the aging-population component. Maps of the positive scores for this component show mixing of urban centers and rural counties (Fig. 4b). Compared to Component 1, while many high-density areas, such as Dongguan, the suburbs of Shenzhen, Zhongshan, Shunde, Huicheng and Huiyang did not have significantly more positive scores for Component 2, some other urban downtowns, such as Xiangzhou (Zhuhai City center), Luohu and Futian (Shenzhen City center), Huangpu and Nansha (Guangzhou City inner suburbs) and Chancheng (Foshan City center), still exhibited high values. In addition, Zhaoqing city's central district (Duanzhou) became prominent for Component 2 in comparison with its formerly low values for Component 1. Meanwhile, part of the hinterland areas, such as Fengkai, Taishan and Kaiping, exhibited high factor scores for the aging component.

Although both the peripheral and central locations show aging trends, they were affected by different social and economic factors. In the countryside, the aging people mainly consisted of peasant farmers whose grown-up children had moved to other places for better employment opportunities and living amenities. The relative rise in the senior population with regard to the urban centers, however, may have resulted from the one-child policy, which was more strictly adhered to in urban communities than in rural villages, and the rising prices of real estate in central build-up zones, which forced young immigrants into daily commuting between the outskirts and the downtowns.

The third component is positively related with the percentage change in those aged 45–59 (Table 5), who commonly have a high level of workplace experience and less of a burden from rearing a family. The spatial pattern of the positive scores for this component was

also complex. On one hand, it mirrored the dual-core structure of the PRD—that is, the downtowns of Guangzhou and Shenzhen (Fig. 4c). On the other hand, some counties in the hinterlands also had high scores, such as Guangning, Deqing, Enping, Taishan and Longmen.

The reasons for the hinterlands having high scores for Component 3 are obviously different from those of the megacity cores, partly due to the rural-urban dual system in the transitional China (Chan and Wei, 2019). The rural residents aged 45–59 were more likely to be agricultural laborers or physical workers who were unable to find jobs in central areas in the PRD because of their low educational levels due to their rural background. By comparison, their counterparts living in megacity cores found it relatively easy to work in consumer services or management and consulting services, as they had accumulated the requisite knowledge and techniques from gaining work experience in private or public corporations. The spatial pattern for the third component also mirrors the future aging trend that will severely affect both the cores and margins in the 2020s in the PRD.

Compared with the duality of the structural PCA results, it is evident that the evolution of the pattern of age structure in the PRD over the 10 years became mixed. This is partly in line with the changing trend in economic functions between the hinterlands and the city centers in the PRD, as manufacturing activities deconcentrated to the hinterlands and knowledge services activities developed in or around multiple centers (Feng et al., 2020). Therefore, we deduced that the age structure change in the PRD possibly had a connection with the pattern of economic change. To decode this question, the next section jointly analyzes the concentration of various age groups and economic activities across the PRD via the LQ method.

4.2 Analyzing the above-average spatial concentration of age groups and economic activities in the Pearl River Delta

The PRD witnessed a great transformation process, from the perspective of functional specification, from 2000 to 2010, according to Feng et al. (2020). At the start of the new millennium, there was a distinct spatial separation in the PRD between KIBS activities, clustered mainly in megacity cores, and manufacturing and intermediate services activities, clustered in highly dense sub-central areas in the PRD. Nevertheless, from a dynamic perspective, positive relative changes in KIBS activities were found to be strongly concentrated in high-density areas and partly in megacity cores (obviously only because of their financial functions). Meanwhile, most of the manufacturing and related services functions were transforming from the high-density areas to medium-density areas and the rural hinterlands.

To identify the importance of, and change in, each type of area in the PRD, in terms of age groups and economic activities, the LQ method was used, based on the absolute number of people falling into one of the six age groups or each economic function in relation to the whole population of the PRD. Fig. 5 shows all the LQ values. The colors of the dots in the figure denote different spatial categories, in line with those presented in Fig. 1.

4.2.1 Analyzing the above-average spatial concentrations of the age groups

In 2000, the different age groups were overrepresented by different spatial categories, and there was a differentiation/duality between urban spaces (red, orange dots in Fig. 5) and rural locations (green dots in Fig. 5). The age groups above 45 and below 14 were highly overrepresented in the hinterlands, while these three age groups were underrepresented in the inner high-density areas (orange dots). By contrast, those aged 15–24 and 25–34 had an above-average concentration in inner high-density areas. Also, the population aged 35–44 had the highest concentrations in megacity cores (red dots), with values for the senior and 45–59 groups also being disproportionately high there. The exception is that the outer high-density areas only show a little overrepresentation of the 25–34 age group.

Although the concentrations of the various age groups remained stable among the areas in the PRD in 2010, the gap between the rural and core areas narrowed significantly over the 10 years. The white and dark-colored dots in Fig. 5a track these changes.

The two hinterlands exhibit a sharp decrease in the concentration of the below-14 group, while the other three spatial categories witnessed an increase in the concentration of this generation. In addition, the concentration of senior people dropped only in the inner hinterland, while, compared with the three urban spatial categories, the outer hinterland showed the smallest rise in the concentration of retired residents. Furthermore, the concentration of middle-aged people, aged 35–59, also

decreased in both of the two hinterlands, while those aged 15–24 became increasingly concentrated in these rural areas.

The most obvious change in the urban areas was the increased concentration of children and the middle-aged (35–59) in the inner high-density areas. Meanwhile, the concentration of those aged 15–24 decreased the most in this spatial category. Megacity cores saw the second largest increase in the concentration of below-14s and the most significant decrease in the concentration of the 35–44 age group. Furthermore, the tendencies of the age groups to become concentrated in megacity cores and inner high-density areas were reverse between 2000 and 2010, indicating a significant transformation in the concentration of young adults and middle-aged residents. Lastly, the outer high-density areas did not exhibit any significant changing trends in age-group concentrations except for a small drop in the 25–34 group.

4.2.2 Analyzing the above-average spatial concentration of economic activities

In order to map the spatial patterns of economic functions in the PRD, we also evaluated the concentration of five types of economic activities using their LQs.

As showed in Fig. 5b, there is also a kind of duality between the PRD core areas and the hinterlands in 2000. Services were highly overrepresented in the megacity cores and manufacturing was highly concentrated in the inner high-density areas in 2000. Meanwhile, the outer high-density areas did not show any concentration except for low-tech manufacturing. By contrast, the rural hinterlands did not specialize in any activities, although economic functions were more represented in the inner hinterland than in the outer hinterland.

Although the economic specialization pattern had not structurally transformed by 2010, the picture is different when we pay attention to the change in economic concentration, which shows narrowing gaps between categories of land in the PRD. Firstly, the concentration of services, especially KIBS, in the megacity cores had decreased significantly, while the high-density areas saw an increase in the concentration of KIBS and goods-related services. Secondly, the hinterlands exhibited positive changes in the concentration of production activities, with the inner hinterland seeing a greater rise in the concentration of high-tech manufacturing and the outer hinterland showing a greater increase in the concentration of low-tech manufacturing. By contrast, the high-density areas saw a significant decrease in the specialization of production, with the outer high-density areas showing a slight increase in high- and medium-tech manufacturing.

5 Discussion

The aim of this study was to explore the connection between demographic and economic changes in a large agglomeration area, using the PRD as a case study. To achieve that aim, PCA and the LQ were used to address the two questions outlined in Section 2.

The first question dealt with the development and changes in different parts of the PRD megacity region, in terms of the importance of location to various demographic and economic groups. We found that:

In 2000, the share of non-working groups in the hinterlands was above average, while the share of working groups in the urbanized areas was above average. At the same time, economic functions were underrepresented in the hinterlands, while services were highly overrep-

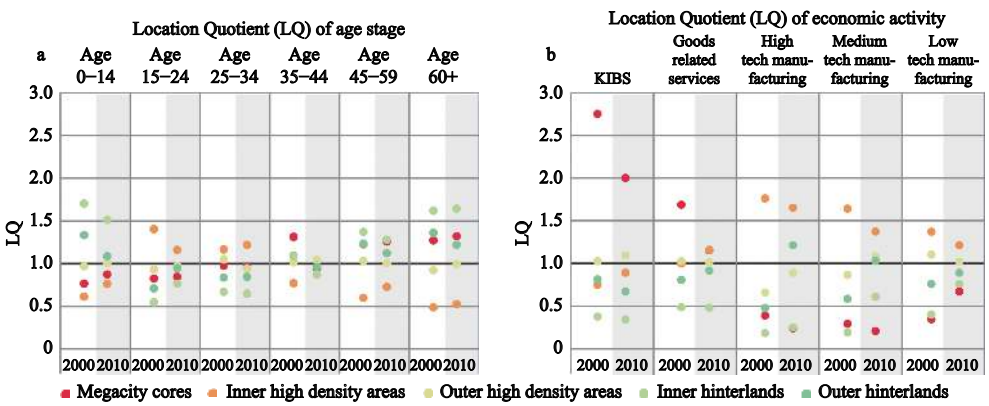

Fig. 5 Location quotients of age groups and economic activities in 2000 and 2010 for each type of areas in the Pearl River Delta

resented in the megacity cores, with manufacturing being highly concentrated in the inner high-density areas.

However, the hinterlands had less of those aged under 14 and more those aged 15–24, this being related to an increase in manufacturing. The inner high-density areas had more of those aged under 14 and less of those aged 15–24, this being related to a *decrease* in manufacturing. This provides evidence for our assumption that there was an increase in the young labor force (older youths or very young adults) in regions where workplaces that did not require a high level of education increased.

In addition, megacity cores lose their attraction as places that appeal to those aged 35–44 and gain in attraction for youths, seniors and the 45–59 group, which is related to a decrease in KIBS specialization. Instead, the inner high-density areas gain most in the 35–44 group, and in the 45–59 and 25–34 groups, this being related to an increase in KIBS specialization. This supports the assumption that, in certain regions, an increase in young and middle-aged adults possibly correlates with increasing knowledge-intensive work that requires a higher education or longer work experience.

The second question dealt with the evolving relationships between different spatial parts of the PRD. We observed a significant transformation in the areas located between the rural hinterlands and the megacity cores, which are the high dense areas in our analysis.

These once-rural areas witnessed intensive industrialization (rural industrialization), appealing to a huge floating population at the end of the 20th century, which led to the emergence of a cluster of urbanized towns and medium-sized urban centers.

However, as the possibility for the hinterlands to become production locations increased from 2000 to 2010, these newly-urbanized, dense areas were losing their advantage in providing physical products, and so the age structure of the employees there became older. At the same time, increasing KIBS and goods-related services were attracted to the high-density areas, when KIBS saturated the mega-city region cores.

To summarize, over the studied period, the population in the high-density areas became older and more knowledge-related during the transformation process. As a result, the clear duality that had previously shaped the rural land and urban cores, whether intra-urban or inside the megacity region, was broken down.

There is some agreement concerning the connection between demographic factors and the economy. In general, the share of young labor is positively related to the regional economy. Wei and Hao (2010) found a correlation between differences in the age structure in various provinces and inter-provincial income disparities. Zhang et al. (2015) argued that there is a positive correlation between a decline in the youth-dependency ratio and the growth rate in GDP per capita between 1989 and 2004. Meanwhile, in China's inland provinces, such as Henan Province, the population aging in rural areas and economic development lagging behind other regions is more serious than in the central cities (Yang et al., 2011).

For the super-megacity regions in China, our findings partially support this (Table 6). For example, the hinterlands attracted some production when the share of young adults increased. This change was probably a reflection of the physical infrastructure development in the PRD. According to Xu and Yeh (2013), Guangdong Province (where the PRD is located) was heavily reliant on highways until the end of 2004, which initially caused an imbalance in traffic accessibility between the core area and the hinterlands of the PRD in 2000 (Hou and Li, 2011). However, with the continued construction of more planned highways, as well as the development of intercity railways or subways, the gaps in traffic connectivity between the cores and hinterlands of the PRD were decreased (Hou and Li, 2011).

The megacity cores in the PRD remained competitive as the age structure transformed to an aging population in China, however. According to Zhou et al. (2015), a lot of middle-income earners live in the Haizhu District in Guangzhou—an area where traditional buildings are still in use—where they perform knowledge-intensive work, such as in the financial and business services and the professional and technical sectors. This serves as an example of the residential patterns of managerial and professional workers decentralizing more slowly than the residential patterns of non-knowledge-related workers (Li, 2010).

The high-density areas between the megacity cores and the hinterlands show great potential for maintaining development. This is supported by the fact that new employment sub-centers have appeared in the suburbs. In Beijing, the new centers can be found primarily along the major highways, leading to statistically significant

Table 6 Comparison between age structure and economic activity in the spatial categories of the PRD from 2000 to 2010

Region	Key findings with regard to employment	Key findings with regard to age/ demographics
Megacity center	In 2000, the area was very highly specialized in KIBS and slightly specialized in goods-related services.Over the 10 yr, service specialization decreased significantly.	In 2000, the area was relatively localized in the above-35 age group, but underrepresented in people aged under 24.Over the 10 years, the degree of localization of the 0–14 age group increased significantly, while that of the 35–44 age group dropped sharply.
High-density region	In 2000, the inner high-density areas specialized in goods-related services and manufacturing. Over the 10 yr, the inner high-density areas saw a small increase in the degree of specialization in KIBS and goods-related services, while the outer high-density areas witnessed a moderate increase in specialization in high- and medium-tech manufacturing. Both lost specialization in low-tech manufacturing.	In 2000, the age structure in the outer high-density areas was the same as in the general PRD, while people aged 15–34 in the inner high-density were disproportionately high. Over the 10 years, the inner high-density areas exhibited a rapid increase in the 35–44 age group, but a sharp decrease in the 15–24 group. The outer areas changed moderately.
Hinterlands	In 2000, the hinterlands did not show specialization in any economic functions.Over the 10 yr, the inner hinterlands saw an increase in goods-related services and manufacturing, while the outer hinterlands saw a significant increase in low-skilled and medium-tech manufacturing.	In 2000, the two hinterland areas exhibited high LQ values for the 0–14 and over 45 age groups. Over the 10 years, both areas saw an increase in residents aged 15–24 and a decrease in the 0–14 and 35–59 age groups.

population distributions (Huang et al., 2017). Some of these sub-centers become edge cities, where industrial parks are located, such as the Nansha District in Guangzhou City (Cheng et al., 2017), and Yizhuang and Kunshan in Beijing and Shanghai, respectively (Wu and Phelps, 2008).

The relocation of residents in the megacity regions is supported by the *hukou* system. According to Zhou (2019), temporary migrants accounted for 40% and 45% of the permanent residents and 91% and 70% of the employees in the PRD in 2000 and 2010, respectively. Zhou (2019) also points out that most temporary immigrants in the PRD migrated from rural areas and have a low educational background, supporting the prosperity of labor-intensive manufacturing in the PRD in 2000s. For most of these non-*hukou* residents, urban villages in former urban-rural fringes provide the possibility for affordable housing (Li and Liu, 2016). The interrelation of changing economic spatial structures are also reflected in spatial patterns of migration. Migration flows of well-educated migrants are spatially much more concentrated and aim for core cities in comparison to less-educated migrants (Liu et al., 2014). This observation fits the changing spatial patterns of labor-intensive industries and knowledge-based services.

The findings of our study also fit with the findings about the relationship of demographic and economic change in other studies (Zhang et al., 2020; Zhang et al., 2021). The studies show a positive relationship between the upgrading of the industrial sectors and the increasing education of permanent and temporary residents. The shift of the industrial structure from labor-intensive to capital-intensive works leads to a changed demand for labour. While labour with primary and junior secondary education is declining, the demand for labour with senior secondary education is increasing (Yang, 2015). These findings are also confirmed for the floating population in six cities in the Pearl River Delta. Based on a questionnaire, conducted in 2018, survey data of the floating population has been identified (Zhang et al., 2020). Comparing three generations of floating migrants, the survey presented results that also support our findings about economic and demographic changes: while the older generation tended to work rather in low-skilled manufacturing jobs, the middle generation is employed in different industries and also managerial employment is relatively high. As education increased even more, the youngest of the three analysed generations shows strong advantages in technical jobs and corporate clerical profession (Zhang et al., 2020). Thus, the intensity of the working experience is reduced while the educational level is improved during time.

6 Conclusions

In this study, we introduced a conceptual framework of changing functional patterns, the changing demographic patterns and urbanization processes in the PRD, with refering to the concept of regional urbanization. We subsequently divided the PRD into five zones based on their population densities and positions, and analyzed

the demographic change and its connection to economic change. Our results shown that, the process of regional urbanization can be identified in the PRD. Highly skilled labour is increasing in core cities and enforcing a process of relocation of labour-intensive work into smaller centers in the region as well as into the regional hinterland. Parallel, demographic changes can be observed. As core cities attract highly educated workers that have experienced university education, also the working beginners are older than working beginners without university education, working in labour intensive manufacturing.

Therefore, we tentatively conclude that during the process of regional urbanization in the PRD between 2000 and 2010, the population in high-density areas reached a middle (older) age and engaged in a more knowledge-based work context. This structural change indicates a maturation of central locations in the PRD in the context of globalized economic processes. Our paper provides a complementary perspective for understanding how economic and demographic changes jointly influence the settlement structure and development of agglomerations. However, there are still open questions concerning developments in polycentric super-megacity regions in China. First, the period the data in this study covers should be extended to more recent years, to incorporate data from the Chinese census of 2020, which will be published sometime in the next few years. However, the last decade (i.e., from 2010 until 2020) still experienced an extraordinary growth in Chinese super-megacity regions, during which the two-child policy that came into effect in 2013, extended in 2015, might have exerted an impact on the demographic structure. Furthermore, apart from the age structure, temporary rural immigration across spatial units is also likely to correlate with economic activities in megacity regions in developing countries, which represents a new research topic for the future.

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