Routledge
Taylor & Francis Group

Journal of the Asia Pacific Economy

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rjap20

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To cite this article: Vinh Q. T. Dang, Fung Kwan & Agnes I. F. Lam (22 Nov 2023): Guangdong – Hong Kong – Macao Greater Bay Area (GBA): economic progress, diversification, and convergence, Journal of the Asia Pacific Economy, DOI: 10.1080/13547860.2023.2284021

To link to this article: https://doi.org/10.1080/13547860.2023.2284021

Published online: 22 Nov 2023.

JOURNAL OF THE ASIA PACIFIC ECONOMY
https://doi.org/10.1080/13547860.2023.2284021

Guangdong – Hong Kong – Macao Greater Bay Area (GBA): economic progress, diversification, and convergence

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ABSTRACT

We use principal component analysis to create three indices that measure the economic development of eleven cities in the Guangdong – Hong Kong – Macao Greater Bay Area (GBA) over 2010–2019. The indices, composed of sixteen socio-economic indicators spanning five dimensions: macro, openness, consumption, human capital, and diversification, track individual cities and the whole region's performance. The Economic Progress Index indicates that the GBA made great strides in all dimensions. The region went through a structural transformation toward services and became more diversified, as confirmed by the Economic Diversification Index. The Economic Convergence Index shows that the cities became more similar in the human capital and consumption dimensions, which is conducive to labor mobility and risk sharing in the region. A comparison with Yangtze River Delta and Beijing-Tianjin-Hebei confirms a rapid integration in the GBA in these two dimensions and calls for more collaboration to promote trade and FDI in less developed GBA cities.

ARTICLE HISTORY
Received 24 October 2023
Accepted 27 October 2023

KEYWORDS
Greater Bay Area; economic progress; diversification; convergence; China

JEL CLASSIFICATION CODES
F10; O19; O10; O50

1. Introduction

The Guangdong-Hong Kong-Macao Greater Bay Area (GBA) comprises China's two Special Administrative Regions (SARs) of Hong Kong and Macao and nine prefecture-level cities surrounding the Pearl River Delta in the southern province of Guangdong: Dongguan, Foshan, Guangzhou, Huizhou, Jiangmen, Shenzhen, Zhaoqing, Zhongshan, and Zhuhai. Among these, Guangzhou and Shenzhen are two of the four first-tier cities in China.[1] As of the end of 2019, the region had a combined population of more than 72 million people and GDP of about 1.7 trillion USD, making it the 12th largest economy in the world.[2] Since 1 July 2017, the central and local governments have publicly supported and promoted a plan of developing the GBA into an innovative, competitive, open, and prosperous economic region similar

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to San Francisco Bay Area, Greater New York, and Greater Tokyo Area. The development plan of GBA was officially issued in February 2019.

Such an ambitious development plan entails not only appropriate initial policy support but also continual measuring and monitoring of the progress so that necessary adjustments can be made to effect more efficient development of the region. Moreover, as any economic transformation of this scale is a complex process, particularly more so for highly dynamic and fast-growing regions, such as the GBA, measuring progress requires an arduous effort of collecting, synthesizing, and interpreting a lot of data. To this end, we develop some simple composite indices that summarize important aspects of socio-economic development in the region.

A diversified economy is propelled by multiple engines of growth and therefore less vulnerable to negative shocks to a particular industry or sector. The Covid-19 pandemic inflicted some GBA cities far more than the others, starkly exposing the urgency of economic diversification to achieve stability and more sustainable growth. Hence, we compute an economic diversification index to measure and trace the breadth of activities in each city. The diversification index also constitutes a dimension in the measure of economic progress, as discussed next.

We capture the economic *progress* in individual GBA cities by synthesizing information contained in sixteen socio-economic indicators across five dimensions: macro, openness, consumption, human capital, and economic diversity. The dimensions and indicators contained therein are selected from a *forward-looking* perspective that accounts for investment in human capital (education and health, for example) and growth besides traditional measures, such as per capita GDP and investment in physical capital. Our Economic Progress Index summarizes economic progress for each GBA city and identifies which city deviates from the group within each dimension and the overall index each year and traces the standing of each city over time.

One key goal of the GBA development plan is to deepen economic cooperation and integration among the 11 regional cities. One often-used measure of integration is the degree of convergence among the constituent members. We calculate the degree of dispersion among the cities in each indicator to derive an Economic Convergence Index that helps track convergence in each dimension and the combination of all five dimensions for the whole region over time.

GBA is part of a growing trend in China in which the government promotes the development of megalopolises, or city clusters, rather than individual cities, through shared physical infrastructure (such as communication and transportation networks) and policies. Two other major megalopolises in China are Yangtze River Delta (YRD) and Beijing-Tianjin-Hebei (BTH), also known as "Jing-Jin-Ji". GBA, YRD, and BTH collectively account for more than one-third and two-thirds of China's GDP and exports, respectively.

YRD consists of Shanghai, nine cities in the province of Jiangsu, eight cities in Zhejiang, and eight cities in Anhui. The development plan of YRD was proposed in 2010 by the National Development and Reform Commission (NDRC), a cabinet-level government agency in charge of macroeconomic management. The YRD urban agglomeration development plan was approved by the State Council in 2016. BTH is composed of Beijing, Tianjin, and eleven cities in Hebei. The outline of the regional

plan for BTH was proposed in 2015 but the specific integration plan is still under consideration.

As the integration plan for YRD was proposed much earlier the integration process in this city cluster may provide some insights for the others. Therefore, we also compute the convergence index for YRD and BTH along different dimensions for a comparison with GBA.

The indices proposed in this study are based on a robust body of industry, policy, and academic publications that popularize the use of composite indices, such as Trade and Development Index developed by the United Nations Conference on Trade and Development (UNCTAD 2007), the KOF Globalization Index (Gygli et al. 2019), Asia-Pacific Regional Integration Index developed by Asian Development Bank (Huh and Park 2018), EU Index for European Economic Integration (Konig and Ohr 2013), Africa Regional Integration Index (ARII. 2020) and the African Infrastructure Development Index (AfDB 2018), both developed by the African Development Bank.[3]

Our work, however, differs from those in the literature in several ways and these differences represent our contributions. First, we analyze three aspects (diversification, progress, and convergence), instead of a single aspect, such as integration (Huh and Park 2018) or infrastructure (AfDB 2018), and therefore offer a more comprehensive look at the development of an economic area. Second, we examine the development at a city level instead of country level. This provides a closer look at parts of a country that are as vast in geography and as diverse in spoken dialects, standard of living, culture, and even genetics (Chan, Dang, and Li 2018; Talhelm et al. 2014) as China. As these GBA cities belong to a single country, they are already integrated according to some common metrics, such as cross-border free movement of goods and people[4] (ARII. 2020) and convergence of macroeconomic policies and regulations, such as tax rates (sale, income, or capital), interest rates, or public debt (Konig and Ohr 2013). Instead, we focus on the indicators that emphasize the economic progress and welfare of the people, such as consumption and human capital. Moreover, the geographic proximity of the cities in the GBA compels us to look at some indicators, such as the flow of tourists, that may not appear important at the country level. The GBA cities share significant cultural values, dialects, customs, and norms; a sizeable portion of tourists do arrive from nearby cities and contribute considerably to the local economy. Lastly, to our best knowledge, our work is the first to construct composite indices for the GBA, an area that is home to one of the most important supply chain networks in the Asia-Pacific region.

A successful development of the GBA requires measuring and monitoring progress in many important socio-economic dimensions as well as activities at firm and household levels. Concerted effort ought to be made to collect and analyze data covering various indicators and aggregation levels to support a comprehensive research program on the advancement of the GBA. Our focus on some specific city-wide economic indicators and dimensions in this study is a step in that direction.

In the next section, we briefly review the literature to motivate the selection of indicators and discuss data sources used in constructing various indices. Section 3 contains the methodology. We present the results in Section 4 and concluding remarks in Section 5.

2. Literature review, indicators, and data

2.1. Literature review and selection of indicators

Many works in the literature examine international economic integration in various regions of the world. Konig and Ohr (2013) designed a composite EU index to capture economic integration in the European Union. Their selection of indicators reflects an emphasis on the dimensions of "single-market" (for example, indicators of cross-border movement of goods, services, labor, and capital), homogeneity (differences in public debt, consumer tax rate, and capital tax rate), and conformity (participation in European Monetary Euro or Schengen, and various compliances with EU laws). For Asia Pacific (AP), Chen and Woo (2010) look at the convergence among the regional economies on five indicators: real GDP per capita, agricultural sectoral share, urban residents, total population, life expectancy, and education expense ratio. Then the convergence is combined with three more indicators – trade share, FDI share, and the share of intra-AP tourist inflows – to produce a composite index of economic integration. Also for Asia Pacific Integration Index, Huh and Park (2018) employ several country-level indicators, such as cross-border equity and bond flows (in the dimension of "Money and Finance Integration"), proportion of other Asian countries that do not require an entry visa or the proportion of intra-regional remittances (in the dimension of "Free Movement of People"), proportion of other Asian countries that have signed Free Trade Agreements, presence of embassy, business investment, or double taxation treaties (in the dimension of "Institutional and Social Integration"). As for the continent of Africa, the Africa Regional integration Index (ARII. 2020) consists of indicators covering the dimensions of infrastructure (e.g. the proportion of intra-regional flights or the average cost of telephone roaming) and productive integration (merchandise trade complementary) in addition to frequently-used indicators spanning the dimensions of trade, financial integration, and free movement of people.

To measure the extent of globalization for individual countries, Gygli et al. (2019) employ variables representing the dimensions of informational globalization (e.g. number of international airports and telephone subscriptions), cultural globalization (e.g. McDonald's restaurant and IKEA stores, civil liberties), and political globalization (e.g. international treaties, international non-governmental organizations, United Nations peacekeeping missions) besides common indicators covering trade and financial integration

Some other studies pay attention to infrastructure and development. For example, AfDB's (2018) Africa Infrastructure Development Index consists of 10 indicators grouped into four dimensions: transport (length of paved roads, total road network), electricity production, internet and communication technology (fixed-line and mobile phone subscriptions, number of internet users, broadband internet subscriptions, internet bandwidth), and water and sanitation (water source and sanitation facilities). UNCTAD's (2007) Trade and Development Index (TDI) puts a greater emphasis on economic and social well-being. Besides the usual measures of trade, finance, and physical infrastructure, the TDI includes indicators that cover human capital (health and education expenditures), economic structure (agricultural value added),

institutional quality (regulatory quality, control of corruption), and macroeconomic stability (inflation, current account balance).

Although our analysis employs a similar methodology to that in the above studies, namely the use of principal component analysis to construct composite indices, our focuses are different. We do not examine integration, infrastructure, or pure economic performance, but rather overall development and progress, with attention to social and welfare development. Moreover, we analyze the development in a region (the Greater Bay Area) completely under the same country (China); the data are city-level and not country-level as in the above studies. Hence, our selection of indicators, in principle, is guided by these objectives.

As the cities in the GBA are located very close to one another, they share many characteristics and can be regarded as integrated by common metrics. For example, virtually all residents in the GBA speak Mandarin, the main dialect in the country, while most in Guangzhou, Hong Kong, and Macao speak Cantonese, a dialect in southern China. They share cultural values such cuisines, customs, and norms. Many residents of the two SARs are descendants of people born in mainland GBA cities, such as Guangzhou, Zhongshan, and Foshan. Mainland cities are a key source of labor supply and raw materials, including food items, for Macao and Hong Kong. For example, the official statistics show that 62% of non-resident workers in Macao in 2019 were from mainland China; and they account for 32% of the total employment in the SAR at that time.[5]

Moreover, the GBA cities are connected by an extensive network of transportation infrastructure, including high-speed trains, bridges, tunnels, and ferries. Although the total population in Macao was only 679,600 in 2019, the combined number of border entries and exits amounted to around 195 million, among which more than 90% occurred at the land and sea border checkpoints with Zhuhai, an adjacent mainland GBA city. This massive volume of people flows consists of tourists from the mainland (which accounted for about 72% of all visitors to Macao in 2019), daily commuters who work or study in Macao and live in Zhuhai or nearby cities, and vice versa, family visits, and people performing other commercial activities. Although the two SARs maintain separate customs and immigration controls from the mainland, border crossing is straightforward for residents of the GBA cities. For example, daily cross-border shopping is common. Recently enacted regulations allow automobiles registered in Macao and Hong Kong to directly drive through and operate in the Guangdong province, of which the nine mainland GBA cities are part. The number of vehicles passing through the border checkpoints has grown exponentially.

Despite geographic proximity and integration, industrial structure and economic development vary considerably across the GBA cities. Guangzhou and Shenzhen have diverse economic activities whereas Macao and Dongguan rely heavily on gaming services and manufacturing, respectively. In 2010, GDP per capita in Macao was about 12 and 10 times that of Zhaoqing and Jiangmen. Hence, we focus on three aspects: economic progress, diversification, and convergence, and select the indicators accordingly. The selection, however, is also constrained by data availability. For example, in the composite Economic Progress Index, time-series data on bilateral flows of goods, services, capital, and people for every pair of cities in the GBA would

be a direct measure of commercial ties in the region, but they simply do not exist because there are no border customs between cities in the same province (Guangdong) to record bilateral commerce.

The Economic Progress Index (EPI) consists of sixteen indicators, grouped into five dimensions: macro, openness, consumption, human capital investment, and economic diversification. The indicators, shown in Table 1, are selected to represent the current conditions as well as progress into future development. In the first two dimensions, the selected indicators are similar to those in the above studies as they capture overall economic conditions and openness. The indicators in the last three dimensions are generally different from those in the literature as they measure social-economic wellbeing, human capital development, and industrial structure. In the following, we discuss how each indicator is defined and the justification for its inclusion in the EPI.

The indicators in the *Macro* dimension represent macroeconomic fundamentals in the cities, such as GDP per capita, annual GDP growth rate, and GDP share of gross capital formation (denoted investment in Table 1). We also include the gross value added of the tertiary sector as a portion of GDP (denoted services) to account for the importance of the service industries; we look at the tertiary sector only, as opposed to both secondary and tertiary sectors, because the goal is to develop the GBA into a high-tech and service-based economic region.[6] Lastly, given the government's commanding role in China's economic development, we also include government spending in each city, scaled by its GDP, in this dimension.

The next group of indicators summarizes the degree of *Openness* in each city: trade (value of exports and imports of goods and services) scaled by GDP; foreign direct investment (FDI) as a portion of GDP, and the number of overnight tourists to the city scaled by the population of that city. Similar indicators are also used to measure trade performance in UNCTAD (2007)'s Trade Development Index.

In the next dimension, we attempt to capture economic well-being at a less aggregated level. The first indicator is annual salary, which is obtained by scaling up monthly salary data. Although GDP per capita is already included in the *Macro* dimension, it may not represent labor earnings for most of the population. For example, Macao's GDP per capita in 2019 was 660,903 MOP, or 81,888 USD, and among the highest in the world, whereas annualized median salary was far lower at 204,00 MOP or 25,276 USD.[7] Change in the cost of living, measured by inflation, is also considered. To be consistent with other indicators in which higher values represent more desirable outcomes, we subtract the average of inflation rates from the

Table 1. Economic progress index: dimensions and indicators.

Economic progress index				
Macro	Openness	Consumption	Human capital	Diversification
• Per capita GDP • GDP growth • Services • Investment • Government spending	• Trade • FDI • Tourists	• Price stability • Annual salary • Energy consumption	• Teacher-student ratio • Health and education expenditure • Hospital beds • Doctors	• Economic diversification index

most recent 3 years from 100; the result, (100 – inflation average), is called "price stability". The next indicator is per capita electricity consumption in the city, calculated as total electricity consumption divided by the population.[8]

The next component in the measure of economic progress contains indicators related to human capital. They are the ratio of teachers to students in primary and secondary schools, proportion of government expenditures spent on health and education, number of hospital beds, and number of medical doctors per 1000 people in each city's population. Except UNCTAD's (2007) Trade and Development Index, which includes adult literacy rate, life expectancy, education expenditure, and health care expenditure, the composite indices in the literature discussed above do not cover this dimension.[9]

The last dimension contains a measure of economic diversity. This measure is not included in the aforementioned literature, except in Gygli et al. (2019) where a similar methodology is used to calculate trade partner diversity, not domestic industrial structure as in our work. A measure of economic diversification is important in the overall assessment of the GBA progress as heavy reliance on a single industry as economic propeller raises vulnerability to unforeseen shocks; Macao's GDP loss by more than half during the first year of the Covid-19 pandemic demonstrates this point clearly. For each GBA city, the whole dimension consists of Economic Diversification Index computed from GDP shares of (i) primary sector, (ii) construction, (iii) manufacturing and other secondary industries, (iv) wholesale and retail trades, (v) transportation, storage, and communication, (vi) accommodation and food services, (vii) financial intermediation, (viii) real estate, and (ix) other tertiary industries.

2.2. Data sources

The data for GBA cities, spanning the period of 2010–2019, are obtained from official statistics published by the local governments of Guangdong, Hong Kong, and Macao as well as the World Bank.[10] These are the data used to generate the results presented in Sections 4.1–4.3. When data are measured in Hong Kong dollar (HKD) or Macao pataca (MOP), they are converted to Renminbi (RMB) based on the official exchange rates before further analysis. The sample period starts in 2010 as this was the year YRD plan was first proposed; moreover, data on some indicators in earlier years are missing for some mainland cities. The latest year for which data are available for all the indicators across the GBA cities is 2019. Data for 2020 are available only for Hong Kong, Macao, and some large cities on the mainland. Moreover, as the 2020 Covid-19 pandemic caused major economic disruption many data series exhibit significant structural break in this year. As an example, Macao's GDP dropped by 56% in 2020. Hence, the currently available data for 2020 are also likely subject to substantial revision.

There are more cities in Yangtze River Delta (YRD) and Beijing-Tianjin-Hebei (BTH). Data availability for smaller cities in these two megalopolises is limited. For example, information on GDP contribution of various industries used in the calculation of Economic Diversification Index in the GBA is not available for Tongling, Shaoxing, Zhenjiang in YRD and Chengde, Handan, Hengshui, and Langfang in

BTH. Another issue is that expenditure components of GDP, such as gross capital formation or government spending, are not available for several cities in YRD and BTH.

Hence, to facilitate a consistent comparison of economic convergence in the GBA with that in the YRD and BTH, we resort to a different data source to ensure the indicators in the Economic Progress Index are defined the same and are available for all cities in the three megalopolises. More specifically, the results in Section 4.4 "Discussion of the differences between the Greater Bay Area and other regions in China" are generated based on data obtained from CEIC database, an often-used data aggregator, with supplementary information from China National Knowledge Infrastructure (CNKI) database, which is an online academic library of academic journals and data, including those from official statistical yearbooks. Some minor modifications on the variables used in the construction of the indices were necessary. Gross capital formation is replaced with fixed asset investment, and government consumption is replaced with general public budgetary expenditures. For the Economic Diversification Index, we resort to a simpler three-sector (primary, secondary, and tertiary) data as they are available for all cities. The results based on this set of more aggregate data are less informative. Nevertheless, they are included in the Appendix A for reference.

3. Methodology

3.1. Economic diversification index

We first discussed the methodology for the Economic Diversification Index as it is an input in the calculation of the Economic Progress Index. Herfindahl-Hirschman (HH), entropy, and ogive indices are common measures of market concentration. We computed all three. The ogive index is a linear transformation of HH index; therefore, both convey the same information. The entropy index provides almost identical results with HH index; the absolute value of the correlation between these two indices is above 0.97 for most cities. We use HH index here because it is the simplest and most commonly used among the three indices.

For each city, HH index is calculated as $\mathrm{HHI} = {s_1}^2 + {s_2}^2 + {s_3}^2 + \ldots + {s_n}^2$, where s_i is the GDP share of industry i. As such, higher values of HHI indicate a greater concentration of economic activities in fewer industries. To be consistent with the rest of the indicators in the next analysis of Economic Progress Index, in which higher values mean more desirable outcomes, we obtain the Economic Diversification Index (EDI) by applying this simple transformation, $\mathrm{EDI} = 1 - \mathrm{HHI}$, for each city in each year. Higher values of EDI indicate more diversified economic activities.

3.2. Economic progress index

3.2.1. Normalization of data

The sixteen indicators in Table 1 are measured in widely different units. For example, per capita GDP is measured in RMB, energy consumption in kWh, trade in percent, and the EDI in the range of 0 to 1. As such, we cannot simply aggregate the

indicators in their original units of measurement to create a composite index. Therefore, the values in each indicator are first normalized based on min-max method, which is a common normalization method (OECD 2008) and used in the United Nations' Human Development Index, Africa Regional Integration Index, and Asia-Pacific Regional Integration Index (Huh and Park 2018), among others.

For each indicator, the values are normalized as $(x_j - x_{\min})/(x_{\max} - x_{\min})$, where $x_{\max}$ and $x_{\min}$ are the maximum and minimum values in the indicator. Bound within [0, 1] range, higher normalized values continue to represent more desirable outcomes, and values that are closer to each other indicate greater similarity between the cities.

3.2.2. Aggregation and weighting of indicators with principal component analysis (PCA)

We aggregate the indicators in two steps. The first step involves combining the indicators in each dimension to an index, except in the diversification dimension where the transformed HH index represents the whole dimension. In the second step, we combine the five dimensional indices into the composite Economic Progress Index.

Aggregating the indicators in each dimension necessitates assigning weights to them. In some studies, the relative importance of each indicator is judged then assigned the weight accordingly while in others, equal weights are assigned to all indicators. Since the final index values are sensitive to the weighting scheme (Lockwood 2004) we avoid making bias-prone subjective judgement. Instead, we let the data "speak" for themselves. To this end, we employ Principal Component Analysis (PCA) to obtain weights.

PCA is a statistical procedure that analyzes the correlation and variation structure of a large data set to reduce its dimensionality to some principal components while retaining most of the information (variation) in the original data set. The weights are determined in the process. PCA is used to determine the weights in the Chicago Fed National Activity Index at the Federal Reserve Bank of Chicago (Evans, Liu, and Pham-Kanter 2002), Dreher's (2006) globalization index, Gygli et al.'s (2019) revised KOF globalization index, Africa Regional Integration Index (ARII. 2020), and Asia-Pacific Regional Integration Index (Huh and Park 2018), among others.

We apply PCA in the first step to obtain weights for the indicators in each dimension (except the diversification dimension); then these indicators are aggregated into dimensional indices. In the second step, PCA is applied again to the five dimensional indices to obtain their weights. This two-step approach is also used in, for example, ARII. (2020) and Chen and Woo (2010).

There is no single universally accepted rule on how many components to be retained from PCA. We use a combination of some commonly-used guidelines. The scree plot is used to check for steep drop-off in the graph of eigenvalues against the number of components. Then to be retained a component must have eigenvalue above 0.7 (Jolliffe's rule), which is less restrictive than Kaiser criterion (eigenvalue $>$ 1) and must contribute at least 10% of variation in the data. In the final results, the eigenvalues of the selected components exceed 1, and amount of explained variation surpasses 80% in most of the cases and 70% in all cases.

As shown in Appendix A, the weights on individual indicators determined by PCA in the construction of the EPI are fairly evenly distributed. No single indicator in a dimension takes a commanding weight over the rest and no single dimensional index dominates the other four either. The individual weights remain stable over time as well. This enhances the usefulness of our indices because they capture information across all indicators and dimensions.[11]

3.3. Economic convergence index

There are several approaches to measuring convergence. Data limitation, however, significantly restricts the number of choices. The short time span of our sample precludes regression estimation of beta convergence. The number of cross-sectional units, which is eleven cities in the GBA, also renders more complex analysis of distribution of the indicators less meaningful. Therefore, we use the coefficient of variation, which is part of the family of sigma-convergence that examines reduction of disparities among the cross-sectional units over time (Monfort 2008). An advantage of the coefficient of variation over other sigma-convergence measures is the ease of interpretation. It has been often used in the literature on economic integration, for example, to gauge convergence in retail markets across ASEAN cities (Dang and Yang 2017), in price level in the European Monetary Union (Rogers 2007), and GDP per capita in European Union regions (Monfort 2008).

The coefficient of variation is computed for each indicator; then it is aggregated across the indicators in each dimension to obtain the dimension index. These five dimensional indices then form the composite Economic Convergence Index. For each indicator and dimension, smaller coefficients of variation indicate less dispersion among the cities or greater convergence over time.

4. Results

4.1. Spatial and temporal variation in economic diversity in the GBA

Table 2 and Figure 1 show the Economic Diversification Index for the cities over 2010–2019. Higher values indicate more diverse economies. The GBA, as a whole, became more diversified over the sample period. The average value of Economic Diversification Index for all the cities is 0.671 in 2010 and rose steadily most of the

Table 2. Economic diversification index, 2010–2019.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Dongguan	0.688	0.692	0.706	0.714	0.717	0.722	0.718	0.714	0.708	0.655
Foshan	0.599	0.602	0.603	0.612	0.604	0.616	0.625	0.649	0.658	0.657
Guangzhou	0.787	0.790	0.798	0.799	0.805	0.806	0.807	0.805	0.802	0.806
Hong Kong	0.685	0.679	0.680	0.686	0.688	0.691	0.689	0.690	0.690	0.685
Huizhou	0.659	0.666	0.669	0.673	0.671	0.685	0.693	0.709	0.709	0.723
Jiangmen	0.676	0.683	0.710	0.716	0.726	0.730	0.734	0.724	0.725	0.768
Macao	0.441	0.415	0.422	0.423	0.468	0.551	0.550	0.530	0.519	0.517
Shenzhen	0.739	0.741	0.753	0.758	0.759	0.764	0.769	0.766	0.768	0.775
Zhaoqing	0.779	0.765	0.753	0.725	0.720	0.716	0.733	0.801	0.808	0.796
Zhongshan	0.644	0.659	0.660	0.658	0.663	0.669	0.682	0.703	0.709	0.728
Zhuhai	0.686	0.689	0.710	0.724	0.736	0.743	0.748	0.752	0.744	0.773

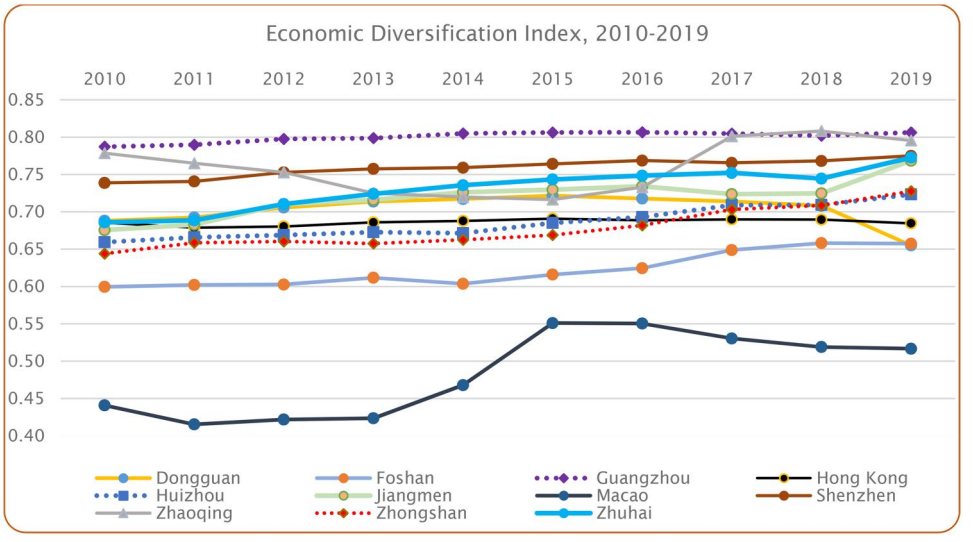

Figure 1. Economic diversification index, 2010–2019.

years, reaching 0.717 in 2019. Economic activities in financial intermediation, real estate services, and social, personal, and other services account for increasingly large share of GDP while those in the primary sector, manufacturing and other secondary industries, and accommodation and food services account for smaller share. These changes demonstrate a clear shift from primary and secondary industries to high value-added services, such as financial transactions, including fintech, and health care not only in more developed cities, such as Guangzhou, Shenzhen, and Hong Kong but in less developed ones like Huizhou, Jiangmen, and Zhaoqing.

The changes in the GBA's economic diversity are consistent with a common pattern of economic development in which cities or countries go through a structural transformation where GDP shares of both agriculture and manufacturing sectors decline while that of the service sector grows. Moreover, in the case of the GBA there is a deliberate policy push, such as the Guangzhou-Dongguan-Shenzhen Science and Technology Innovation Corridor blueprint, to transform the region into an area of innovation in biotech, fintech, artificial intelligence, robotics, and high-end manufacturing.[12] Looking ahead, the region is expected to continue its diversification trajectory in line with the policy directives.

Guangzhou was consistently the most diverse economy in the region, followed by Shenzhen. They are two of four first-tier cities in China. Zhaoqing's diversification score was relatively high but it fluctuated substantially. Zhuhai registered a steady increase in economic diversity in the period; so did Jiangmen, Huizhou, and Zhongshan. Hong Kong's diversification level, placing below the median, remained stable in the period. Due to a significant drop in 2019, Dongguan is the only economy in the region that became less diverse in the sample period.

The least-diversified GBA economies are Foshan and, particularly, Macao, although both improved considerably in the period. In the case of Macao, the spike in diversification score in 2014–2015 coincided with a large drop in the growth rate of the gaming sector, which reduced its dominance in the economy. The recovery of the

gaming sector afterward coincides with a decrease in the diversification score. At the end of the 2010–2019 period, there is still a considerable gap in the level of diversification between Foshan and Hong Kong, reflecting the former's concentration of economic activities in manufacturing. But this gap pales in comparison with that between Macao and Foshan, highlighting the fact that Macao's economy remained over-reliant on the gaming sector.

4.2. Economic progress and development in the Greater Bay Area

The values of sixteen indicators for 2010, 2019, and for the average over the period of 2010–2019 are presented in Tables 3–5, respectively. The data show that the Greater Bay Area made considerable progress across all dimensions. In the *Macro* dimension, per capita GDP rose by about 60% in the region in the sample period from 88,428 RMB in 2010 to 140,505 RMB in 2019.[13] Although GDP growth rates are lower at the end of the sample it is consistent with the "catch-up" effect, a phenomenon in which economies tend to grow faster at the earlier stages of development and then slow down later. Moreover, as shown in Table 3, the 2010–2019 average growth rate is still substantial, above 8% for the whole region. The growth prospect of the region remains promising as the investment rate (% of GDP) continued to rise from an already high level at the beginning of the period. Government spending also increased for less developed cities as part of fiscal support for their development while remained stable for more developed cities.

As another clear sign of the structural transformation of the GBA economy, services played a more important role in the economy, accounting for a larger share of GDP at the end of the sample (an average of 65.5% in 2019 *vs.* 62.1% in 2010). The regional economies, particularly those in the mainland, had gradually shifted away from being simply a manufacturing base for exports. This explains the fall in GDP share of trade and FDI in the *Openness* dimension during the sample period as a substantial part of the foreign investment in the region had been targeted at producing export goods. These changes are also in conformance with the overall national development strategy of increasing reliance on domestic consumption, rather than exports, as a new engine of growth. The last indicator in the *Openness* dimension shows that cities across the region uniformly attracted more tourists in the sample period.

Consumption is another dimension where there was significant progress in the welfare of the residents in the GBA region. The price stability remained similar in the period, indicating a stable economic environment where inflation was well controlled. The average employment earning more than doubled, rising from 53,755 RMB in 2010 to 113,089 RMB in 2019. This is remarkable since it far exceeds the growth in GDP per capita discussed above. As another indication of the higher standard of living, the electricity consumption per person increased substantially in all the cities during the sample period.

In the *Human Capital* dimension, government spending on health care and education rose significantly in most cities in the region. This policy support and other social investments resulted in clear improvement in the number of teachers, hospital beds, and doctors for the residents in every GBA cities. The progress in dimension is

Table 3. Indicators in the economic progress index, 2010.

	Guangzhou	Shenzhen	Zhuhai	Foshan	Huizhou	Dongguan	Zhongshan	Jiangmen	Zhaoqing	Hong Kong	Macao
Macro											
Per capita GDP, RMB	88,361	98,437	79,002	80,794	38,917	53,575	61,691	35,873	28,198	219,844	354,613
GDP growth, %	13.20	12.20	13.20	14.30	18.30	10.40	14.20	14.50	17.20	6.77	25.26
Services, % of GDP	60.39	50.51	41.95	35.24	34.90	48.02	38.65	36.75	40.12	90.91	95.02
Investment, % of GDP	30.72	20.07	39.82	28.65	51.42	24.40	32.36	34.17	40.75	23.89	13.30
Government spending, %	13.57	6.56	11.10	8.20	9.08	7.27	6.46	8.59	15.53	8.86	8.24
Openness											
Trade, % of GDP	64.68	234.69	240.12	61.51	133.04	190.99	112.16	61.35	27.17	404.77	120.44
FDI, % of GDP	2.48	2.91	6.76	2.34	5.59	4.29	2.41	4.74	5.78	36.17	12.90
Tourists	3.55	3.17	8.84	1.20	2.33	1.89	1.88	2.23	2.69	2.85	22.06
Consumption											
Price stability, %	97.80	97.30	98.47	97.87	98.00	98.27	98.13	98.10	98.03	97.60	95.80
Average salary, RMB	54,807	50,455	34,405	37,078	29,599	46,576	40,577	27,496	30,114	135,393	91,370
Energy, Kwh/per capita	4925	6398	6549	6432	4183	6833	5977	3712	2679	6306	6762
Human capital											
Teacher-student ratio	0.060	0.058	0.053	0.055	0.054	0.050	0.053	0.059	0.056	0.066	0.068
Health and education, %	11.13	32.68	23.49	17.81	27.27	22.55	35.46	25.90	20.86	41.30	48.31
Hospital beds	4.92	2.20	4.21	3.23	2.65	2.43	3.24	2.83	2.48	5.04	2.17
Doctors	2.64	2.05	2.96	1.62	1.35	1.43	1.72	1.45	1.21	1.79	2.46
Diversification											
Diversification index	0.787	0.739	0.686	0.599	0.659	0.688	0.644	0.676	0.779	0.685	0.441

Notes: Government spending is calculated as a percentage of GDP. Trade: sum of exports and imports, %of GDP; Tourists: overnight tourists, person-times scaled by population; Price stability: 100 – average of inflation rate is the most recent 3 years; Energy: electricity consumption divided by population, in kWh; Health and education: government expenditures on health care and education, % of total government spending; Hospital beds: number of hospital beds per 1000 people in the population; Doctors: number of medical doctors per 1000 people in the population; Diversification index: maximum value is 1 and minimum value is 0; higher numbers indicate more diverse economic activities.
Data sources: These statistics are calculated based on data obtained from
Provincial government of Guangdong: http://stats.gd.gov.cn/gdtjnj/index.html.
Government of Hong Kong SAR: https://www.censtatd.gov.hk/.
Government of Macao SAR: https://www.dsec.gov.mo/.
The World Bank: https://data.worldbank.org/.

Table 4. Indicators in the economic progress index, 2019.

	Guangzhou	Shenzhen	Zhuhai	Foshan	Huizhou	Dongguan	Zhongshan	Jiangmen	Zhaoqing	Hong Kong	Macao
Macro											
Per capita GDP, RMB	156,427	203,489	175,533	133,850	86,043	112,507	92,709	68,194	53,936	336,846	553,075
GDP growth, %	6.80	6.71	6.80	6.90	4.20	7.42	1.20	4.30	6.26	−1.25	−4.71
Services, % of GDP	71.62	60.93	53.84	42.32	43.16	43.16	48.91	48.94	41.68	89.32	95.58
Investment, % of GDP	34.65	30.82	69.94	38.07	49.13	28.79	37.64	42.32	43.71	18.87	14.19
Government spending, %	13.03	8.92	11.20	8.74	12.31	9.60	6.66	8.90	13.89	10.78	10.31
Openness											
Trade, % of GDP	42.35	110.56	84.76	44.96	65.00	145.95	77.14	45.36	17.99	353.23	116.94
FDI, % of GDP	1.94	1.98	4.77	0.48	1.54	0.93	1.19	1.73	0.42	15.94	12.04
Tourists	4.43	5.00	12.87	2.37	4.91	2.72	4.43	6.46	3.42	3.16	27.42
Consumption											
Price stability, %	97.43	97.47	98.20	97.73	97.73	97.53	97.97	97.90	97.87	97.75	97.67
Average salary, RMB	123,498	127,757	100,878	86,401	83,639	74,017	85,691	80,332	80,271	206,192	174,807
Energy, Kwh/per capita	6570	7240	9384	8612	8727	10,050	9173	6365	4309	5957	8543
Human capital											
Teacher-student ratio	0.075	0.085	0.067	0.066	0.066	0.069	0.067	0.064	0.063	0.082	0.089
Health and education, %	25.02	43.81	37.26	27.78	36.66	27.34	48.73	47.17	35.43	42.59	47.74
Hospital beds	6.54	3.58	5.06	4.67	4.48	3.90	4.77	5.24	4.41	5.51	2.40
Doctors	3.83	3.00	3.82	2.57	2.87	2.46	2.76	2.36	2.02	2.00	2.66
Diversification											
Diversification index	0.806	0.775	0.773	0.657	0.723	0.655	0.728	0.768	0.796	0.685	0.517

Notes: Government spending is calculated as a percentage of GDP. Trade: sum of exports and imports, % of GDP; Tourists: overnight tourists, person-times scaled by population; Price stability: 100 – average of inflation rate is the most recent 3 years; Energy: electricity consumption divided by population, in kWh; Health and education: government expenditures on health care and education, % of total government spending; Hospital beds: number of hospital beds per 1000 people in the population; Doctors: number of medical doctors per 1000 people in the population; Diversification index: maximum value is 1 and minimum value is 0; higher numbers indicate more diverse economic activities.
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Table 5. Indicators in the economic progress index, 2010–2019 average.

	Guangzhou	Shenzhen	Zhuhai	Foshan	Huizhou	Dongguan	Zhongshan	Jiangmen	Zhaoqing	Hong Kong	Macao
Macro											
Per capita GDP, RMB	128,964	154,532	124,916	107,426	65,048	77,617	89,199	50,614	44,690	268,981	488,927
GDP growth, %	9.19	9.29	9.75	9.00	10.51	8.15	8.64	8.94	9.59	2.91	5.45
Services, % of GDP	66.15	56.09	46.92	37.81	39.05	50.25	43.79	42.31	39.69	90.20	94.89
Investment, % of GDP	33.23	25.51	60.99	34.31	50.77	26.27	36.07	39.37	42.40	22.71	17.30
Government spending, %	12.97	7.80	10.55	8.31	10.99	8.58	6.57	8.78	14.43	9.56	8.60
Openness											
Trade, % of GDP	49.21	173.04	160.95	52.87	106.20	168.69	81.63	55.96	23.39	399.39	117.90
FDI, % of GDP	1.99	2.31	6.06	1.62	3.25	3.40	1.46	2.41	3.16	35.55	6.04
Tourists	4.04	4.38	11.42	1.71	3.83	2.29	3.14	3.99	3.13	3.48	24.30
Consumption											
Price stability, %	97.38	97.35	97.76	97.53	97.66	97.71	97.93	97.69	97.69	96.83	95.90
Average salary, RMB	82,419	81,031	65,434	59,838	56,306	56,089	59,782	52,169	52,809	164,236	130,409
Energy, Kwh/per capita	5738	6917	8305	7741	6248	8198	7540	5101	3667	6157	7722
Human capital											
Teacher-student ratio	0.069	0.073	0.062	0.061	0.062	0.061	0.063	0.063	0.063	0.075	0.080
Health and education, %	18.25	37.11	32.79	24.23	36.61	27.00	41.68	40.52	29.12	41.25	49.19
Hospital beds	5.86	2.90	4.90	4.10	4.05	3.24	4.09	4.18	3.51	5.23	2.32
Doctors	3.18	2.52	3.30	2.08	2.13	1.86	2.14	1.88	1.58	1.87	2.58
Diversification											
Diversification index	0.800	0.759	0.731	0.622	0.686	0.703	0.677	0.719	0.760	0.686	0.484

Notes: Government spending is calculated as a percentage of GDP. Trade: sum of exports and imports, % of GDP; Tourists: overnight tourists, person-times scaled by population; Price stability: 100 – average of inflation rate is the most recent 3 years; Energy: electricity consumption divided by population, in kWh; Health and education: government expenditures on health care and education, % of total government spending; Hospital beds: number of hospital beds per 1000 people in the population; Doctors: number of medical doctors per 1000 people in the population; Diversification index: maximum value is 1 and minimum value is 0; higher numbers indicate more diverse economic activities.
Data sources: These statistics are calculated based on data obtained from
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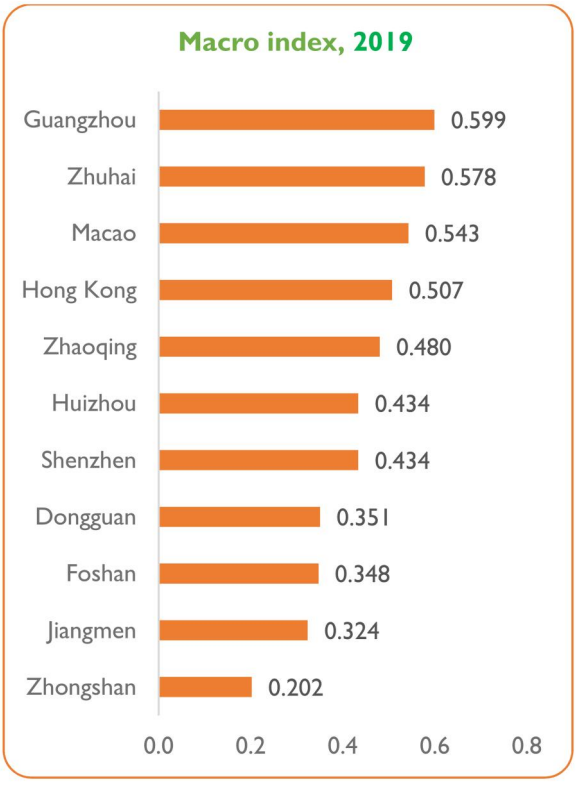

Figure 2. Macro index, 2019.

expected to have long lasting impact in not only sustainable economic growth but also the integration of the region.

Figures 2–5 depict 2019 index value in the dimensions of *Macro*, *Openness*, *Consumption*, and *Human Capital*, respectively. The data show that among the mainland GBA cities, Guangzhou and Shenzhen are high performers in the majority of indicators and dimensions, which is expected given how well-developed their economies have already been. For example, over the period of 2010–2019, Guangzhou is consistently the most diverse economy in the region, has the largest GDP share of tertiary industries among the mainland GBA cities, and highest scores in some human capital indicators. Guangzhou also performs well in other indicators, such as per capita GDP, economic growth, and salary. Based on 2019 data, Guangzhou registered the top score in *Macro* and *Human Capital* dimensions. Compared to other cities in the region, however, Guangzhou is less open as the trade and tourist ratios indicate. Guangzhou's inflation is the highest while its energy consumption is among the lowest. This explains its low standing in the *Openness* and *Consumption* dimensions. Shenzhen registers the highest GDP per capita, salary, and the second highest trade ratio among the mainland GBA cities. It also performs well in three of the four *Human Capital* indicators, thereby scoring the second highest in this dimension based on 2019 data.

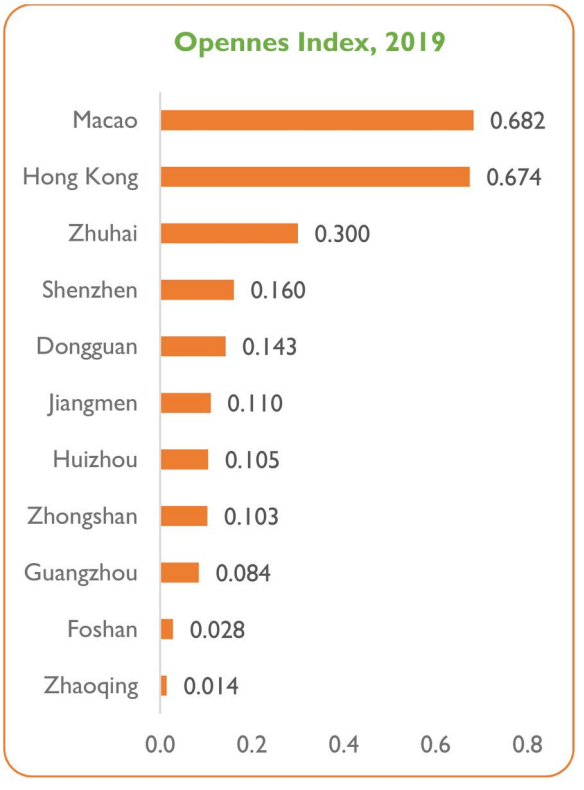

Figure 3. Openness index, 2019.

Zhuhai, however, stands out above the rest in most indicators. It exhibits the second highest average growth rate (9.75%) among the regional economies in the period, propelling its per capita GDP from 79,002 RMB, which was below Guangzhou's value of 88,361 RMB in 2010 to 175,533 RMB, well above Guangzhou's value of 156,427 RMB in 2019. Part of Zhuhai's fast growth can be attributed to its investment; for example, in 2019, at 69.9% of GDP, it is the highest investment rate in the region and more than twice the rate of Guangzhou (34.6%). Among the mainland GBA cities in 2019, Zhuhai also scored the highest in these indicators: FDI, tourists, price stability (i.e. low inflation), and the number of doctors. Consequently, Zhuhai is placed among the top three in all four dimensions.

Foshan and Dongguan, due to their traditional manufacturing base, have a small service sector. They are the least diversified economies among the mainland GBA cities. As shown above, Dongguan is the only city that became less diversified in the period. While per capita GDP of Dongguan is well above that of Zhongshan, Huizhou, Jiangmen, and Zhaoqing in 2019, its average salary is well below that in these four cities. This reflects significant capital flows into manufacturing in Dongguan from outside investors for export goods, contributing a lot more to GDP than to the salary of an average person. Dongguan's international trade, at 146% of GDP, is the highest among the mainland GBA cities. Foshan's international trade, at around 45% of GDP, is among the lowest. Both Foshan and Dongguan also have low

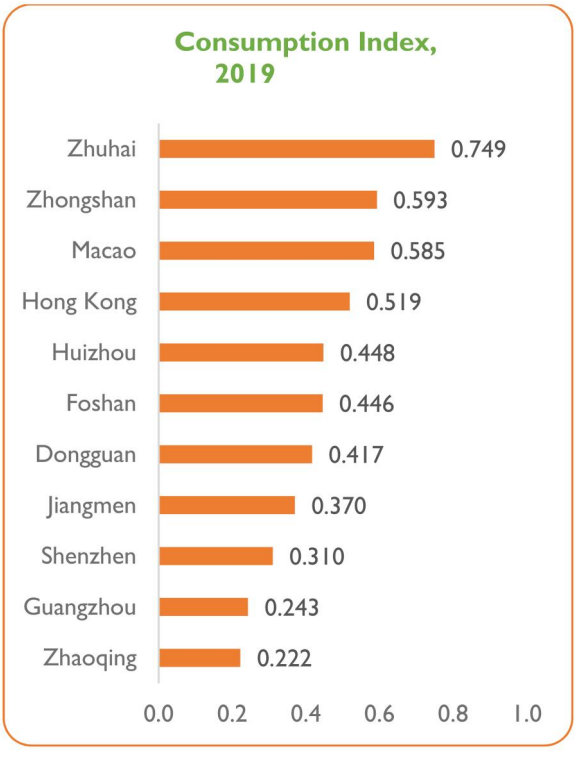

Figure 4. Consumption index, 2019.

scores in these indicators: FDI, tourists, government spending on health and education, and number of doctors and hospital beds. As a result, these two cities are placed toward to bottom in the four dimensions.

Zhongshan performs well in the C*onsumption* dimension, particularly price stability. For other dimensions, however, it scores in either in the middle or lower. Huizhou, Jiangmen, and Zhaoqing are the three least developed cities in the GBA, as partly reflected by their GDP per capita. However, in some dimensions, they score above the more developed Foshan and Dongguan. For example, Huizhou has the highest average growth rate over the period of 2011–2019 among all 11 GBA cities. The salary level in Huizhou, Jiangmen, and Zhaoqing is higher than that in Dongguan. In 2019, these three cities have higher scores in the investment, overall government spending, tourists, price stability, government spending on healthcare and education, and hospital beds than either Dongguan or Foshan or both.

The two Special Administrative Regions of Hong Kong and Macao register much higher scores than the majority of the mainland GBA cities in most all indicators, particularly those in the *Openness* dimension. These are reflected by their placements in the four dimensions. Both SARs, however, experienced much less stable and lower average economic growth in the period; their GDP growth rate turned negative in 2019. Macao, due to its heavy dependence on the gaming sectors, consistently has the lowest score in the diversification index.

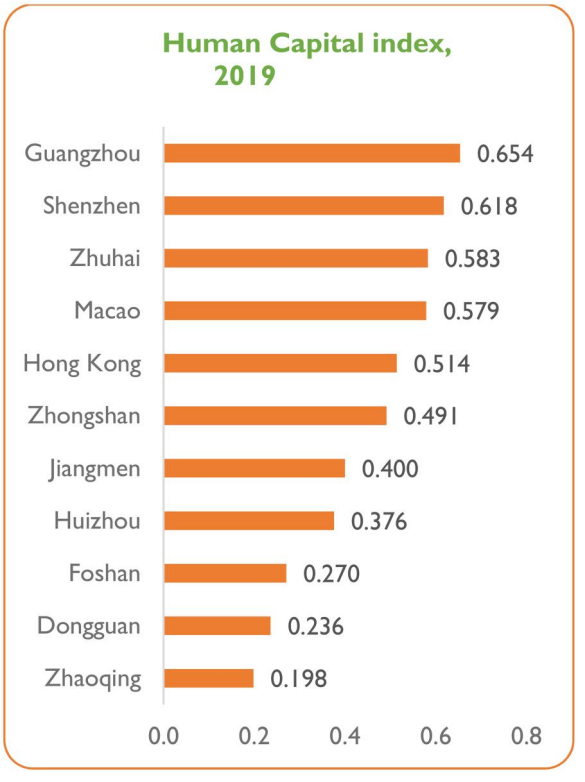

Figure 5. Human capital index, 2019.

The index scores for the four dimensions shown in Figures 2–5 are combined with the diversification index, shown in Figure 1, to generate the Economic Progress Index (EPI) for each city in each year. Figure 6 shows the EPI for 2019. By construction, higher values of EPI reflect, on average, higher scores in the sixteen indicators across five dimensions.

The EPI of the top five cities appears to conform to prior expectations. Hong Kong and Zhuhai scored the highest at 0.588 and 0.581, respectively. It is followed by Guangzhou (0.518). As shown in Tables 3 and 4, these three cities perform well in the majority of the indicators across all dimensions.

Shenzhen and Macao have similar scores, 0.476 and 0.470, respectively. These two economies are quite different and display their strengths in different dimensions. For example, Macao has an advantage in the *Openness* dimension but also a disadvantage in the *Diversification* dimension.

A seemingly peculiar result, however, is that the EPI scores of Jiangmen, Huizhou, Zhaoqing are higher than those of Foshan and Dongguan. But as pointed out above, although Jiangmen, Huizhou, and Zhaoqing are less developed, they have made some significant *progress* in several socio-economic aspects nested in the indicators. As the 2019 statistics in Table 4 show, Jiangmen scores higher than Foshan and Dongguan in 10 and 9 indicators, respectively, mainly along the dimensions of *openness*, *human capital*, and *diversification*. Huizhou scores higher than both Foshan and Dongguan in 10 indicators in the same three dimensions. Although Zhaoqing scores higher than

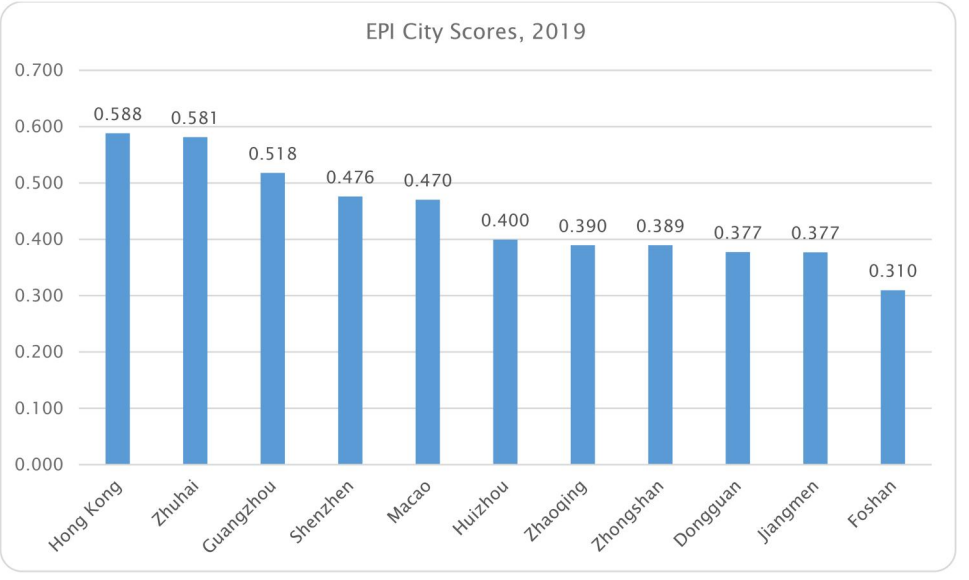

Figure 6. EPI city scores, 2019.

Foshan and Donguan only in 6 and 8 indicators, respectively, but one indicator, the diversification index, constitutes the whole dimension of *Diversification* and therefore carries a significant weight.

It is encouraging that the three less developed cities of Jiangmen, Huizhou, and Zhaoqing perform relatively well in the dimensions of *Openness*, *Human Capital*, and *Diversification*. These dimensions are important components of higher quality and more sustainable economic development in the region.

Table 6 and Figure 7 present the city placement based on the Economic Progress Index over the period of 2010–2019. Hong Kong, Zhuhai, Guangzhou, and Shenzhen consistently occupied the top four positions for their high growth, open economy, large human and physical capital investment, and diverse economic activities.

Macao takes the fifth spot for high scores in *Macro*, *Openness*, and *Human Capital* dimensions except for a significant drop in 2014 because of a sharp downturn in the gaming sector and related tourism businesses. Huizhou made significant progress in the period with the highest average GDP growth rate, stimulated by the second-highest investment rate in the region. It also scores above the median in the *Openness* dimension. Zhaoqing's EPI scores fluctuate substantially, mirroring its diversification index. Large variation in the period is also observed for Zhongshan, Dongguan, and Jiangmen. Foshan scored very low in most indicators throughout the period.

4.3. Similarity and disparity among the Greater Bay Area cities

Figure 8 presents the results from the Economic Convergence Index (ECI) in the five dimensions for 2019; smaller values indicate greater convergence. The results are consistent with the dispersion observed in each of the five dimensions (Figures 1–5). The GBA cities differ the most in the *Openness* dimension, demonstrated by large

Table 6. EPI city placement, 2010–2019.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Hong Kong	1	1	1	1	1	1	2	2	1	1
Zhuhai	2	2	2	2	2	2	1	1	2	2
Guangzhou	3	3	3	3	3	3	3	3	3	3
Shenzhen	5	4	4	4	4	4	4	4	4	4
Macao	4	5	5	5	7	6	7	6	5	5
Huizhou	9	10	8	6	5	5	5	5	6	6
Zhaoqing	7	6	6	10	10	10	10	10	8	7
Zhongshan	6	7	7	9	8	8	8	7	7	8
Dongguan	10	8	9	7	6	7	6	8	10	9
Jiangmen	8	9	10	8	9	9	9	9	9	10
Foshan	11	11	11	11	11	11	11	11	11	11

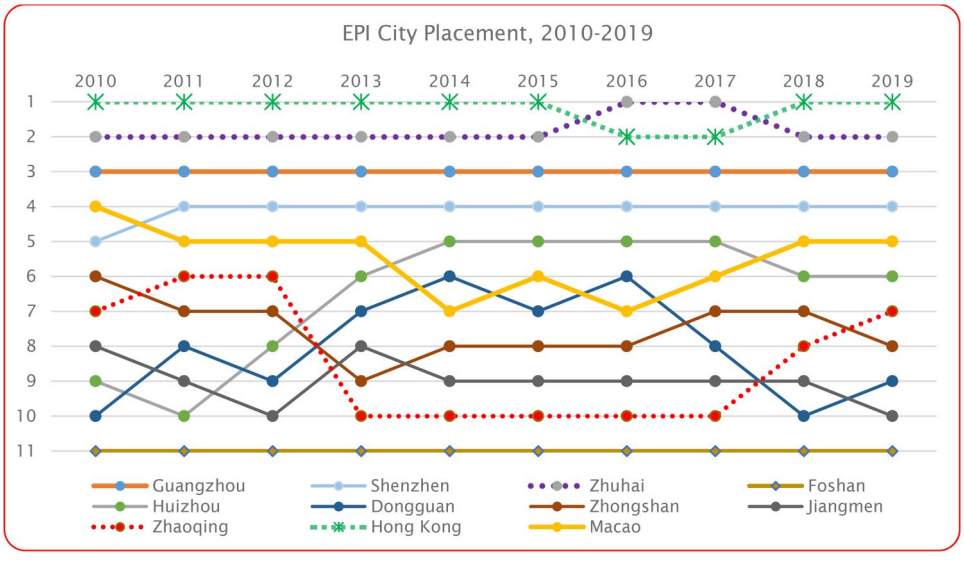

Figure 7. EPI city placement, 2010–2019.

disparities among the cities in Figure 3. The economies of Hong Kong and Macao, the two former European colonies, are much more open than most of the mainland cities. For example, Table 4 shows that in 2019 trade varied from 352 and 117% of GDP in Hong Kong and Macao, respectively to 18 and 42% of GDP in Zhaoqing and Guangzhou, respectively. FDI, as a percentage of GDP, is as large as 16% in Hong Kong and as small as 0.4% in Zhaoqing.

Macro is another dimension where the regional economies are dissimilar. This is driven partly by a large gap between GDP per capita in Hong Kong and Macao and that in the mainland GBA cities. Moreover, their economic growth rates can deviate considerably from the rest of the region. This, in itself, is not a cause for concern because of catch-up effects: less developed cities are expected to register faster growth due to higher investment and support from government spending.

The GBA cities are much more similar in *Human Capital* and *Consumption* dimensions; the ECI values for these two dimensions are 0.203 and 0.207,

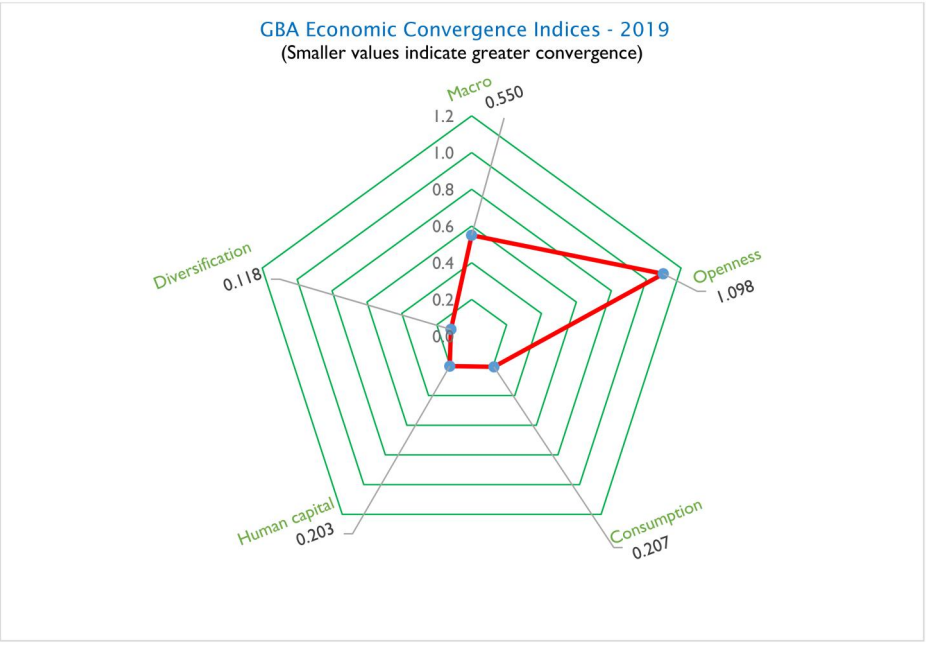

Figure 8. GBA economic convergence index, 2019 (smaller values indicate greater convergence).

respectively, in Figure 8. This can be seen from examining the distribution in Figures 4 and 5; the difference among the GBA cities in these two dimensions is much smaller compared with that in the *Macro* and *Openness* dimensions (Figures 2 and 3). This is a positive development for the GBA as greater convergence in *Human Capital* and *Consumption* promotes labor mobility and risk sharing among the residents in the region, two essential ingredients in the creation of a knowledge-based economic region that shares a common pool of human resources.

Lastly, although Macao depends heavily on the gaming sector and Dongguan and Foshan have been manufacturing hubs in the region, the rest of the cities are reasonably diversified. This is reflected by the ECI index of 0.118 in Figure 8.

Figure 9 depicts the time path of convergence in the five dimensions and the overall Economic Progress Index from 2010 to 2019. Notably, the *Openness* and *Macro* dimensions, where there are large disparities among the cities, display considerable fluctuations but no significant convergence over time. The large spike in the convergence index value for *Macro* dimension in 2015 was driven by negative GDP growth rate in Macao (−21.6%) and then again in 2019 by economic downturn in both Macao and Hong Kong. For *Openness* dimension, the index value rose in 2014 and remained elevated until 2018 because of a significant increase in the variation of the FDI among the cities. More specifically, Zhuhai and Hong Kong received much more FDI whereas Foshan, Zhongshan, Jiangmen, Zhaoqing, and Huizhou received much less.

There was significant convergence in the *Consumption* dimension across all three indicators. The largest reduction in the disparities among the cities, however, was achieved in the average earnings. For example, Table 3 shows that in 2010 the salary

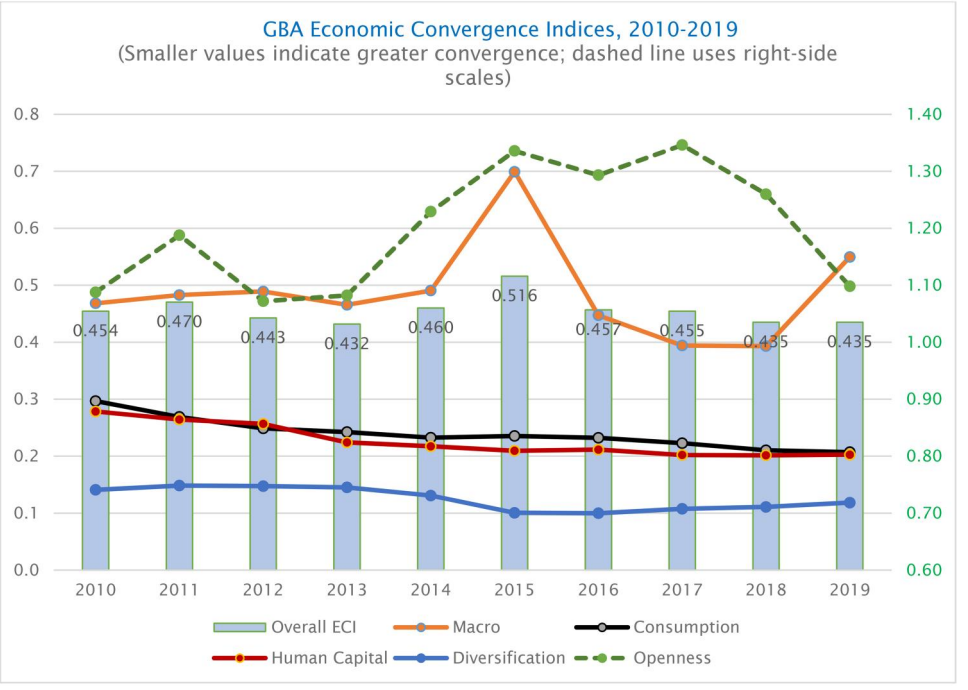

Figure 9. GBA economic convergence indices, 2010–2019 (smaller values indicate greater convergence; dashed line uses right-side scales).

among the mainland cities was highest in Guangzhou and lowest in Jiangmen; the ratio between them was about 2. As shown in Table 4, the ratio between these two cities fell to 1.5 in 2019; and the ratio between the highest (Shenzhen) and lowest (Dongguan) salary decreased to 1.7.

The GBA cities also converge considerably in the *Human Capital* dimension. First, as presented in Tables 3 and 4, the teacher-student ratio, government spending on health and education, hospital beds, and doctors rose from 2010 to 2019 across all cities, showing clear progress in the investment of human capital. Second, there is less dispersion among the cities in the last three indicators.

The convergence index in Figure 9 indicates the cities became more similar in terms of economic diversity as well. As shown in Figure 1, there is much less dispersion in the Economic Diversification Index among the cities over the period of 2010–2019 as most GBA cities, except Dongguan, became more diversified.

In short, the GBA cities are dissimilar in some macroeconomic fundamentals and openness because there are still sizable gaps between the more developed and less developed mainland GBA cities as well as those between the two Special Administrative Regions of Hong Kong and Macao and the mainland GBA cities. The region is much more similar in terms of human capital development and economic welfare. Moreover, there is clear evidence of steady convergence over time among in the GBA in the dimensions of *Human Capital*, *Consumption*, and *Economic Diversification*.

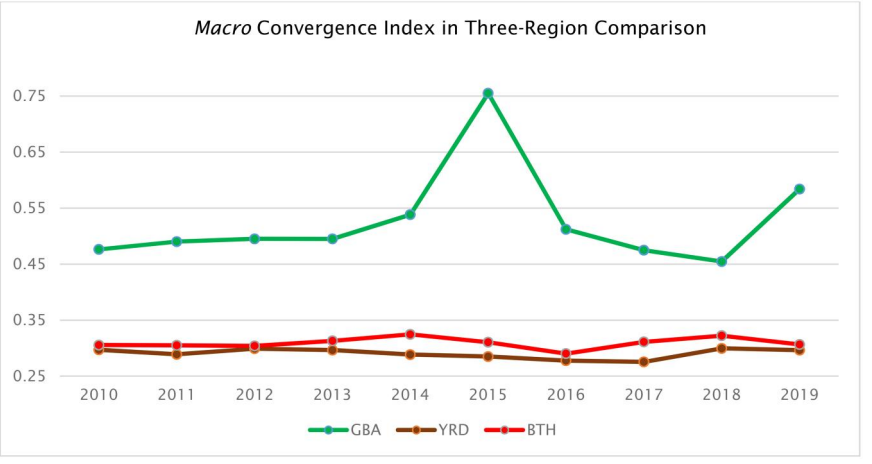

Figure 10. Macro convergence index in three-region comparison.

4.4. Discussion of some differences between the Greater Bay Area with other regions in China

In this section, we compare the process of convergence among the three megalopolises: the Greater Bay Area (GBA), Yangtze River Delta (YRD), and Beijing-Tianjin-Hebei (BTH). YRD consists of Shanghai, nine cities in the province of Jiangsu (Changhou, Nanjing, Nantong, Suzhou, Taizhou, Wuxi, Yancheng, Yangzhou, and Zhengjiang), eight cities in Zhejiang (Hangzhou, Ningbo, Jiaxing, Huzhou, Shaoxing, Jinhua, Zhoushan, and Taizhou), and eight cities in Anhui (Hefei, Wuhu, Ma'anshan, Tongling, Anqing, Chuzhou, Chizhou, Xuancheng). BTH is composed of Beijing, Tianjin, and eleven cities in Hebei (Baoding, Cangzhou, Chengde, Handan, Hengshui, Langfang, Qinghuangdao, Shijiazhuang, Tangshan, Xingtai, and Zhangjiakou). There are more cities in YRD and BTH than in GBA. Except for municipalities, such as Beijing, Tianjin, and provincial capital cities, such as Nanjing and Hangzhou, the average size, in terms of population or GDP, of the rest of the cities in YRD and BTH is smaller than that of the cities in GBA, asides from the two municipalities of Guangzhou and Shenzhen.

Figure 10 shows that cities in GBA is considerably more divergent in the *Macro* dimension than those in YRD and BTH. As mentioned above, the economic downturn in Macao in 2014 and in both Hong Kong and Macao in 2019 give rise to large spike and, consequently, the apparent large fluctuations in the convergence index for GBA. Over this period, there was no discernable convergence in this dimension in all three regions.

The GBA cities are also far more divergent in the *Openness* dimension than those in the other two megalopolises, as shown in Figure 11. Notably, the level of dispersion among the cities in BTH was similar to that in GBA at the beginning of the period, but the former achieved significant convergence in the period. On the other hand, there was more divergence in this dimension for YRD; its convergence index was similar to that in BTH at the end of the period.

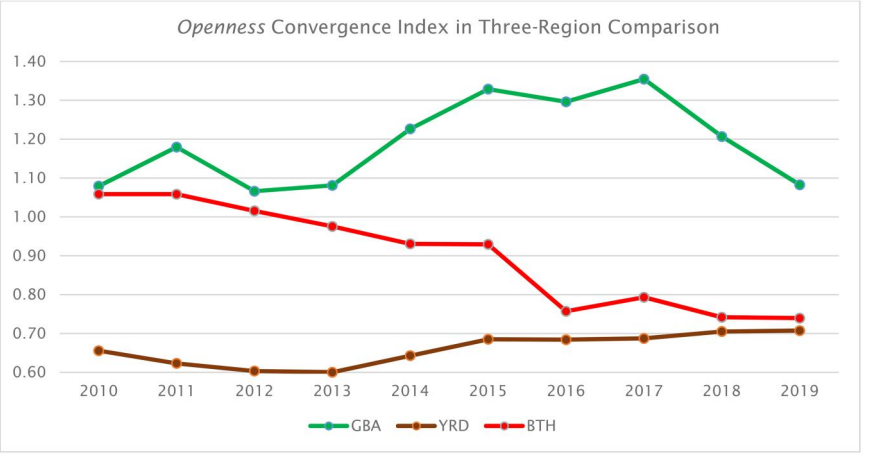

Figure 11. Openness convergence index in three-region comparison.

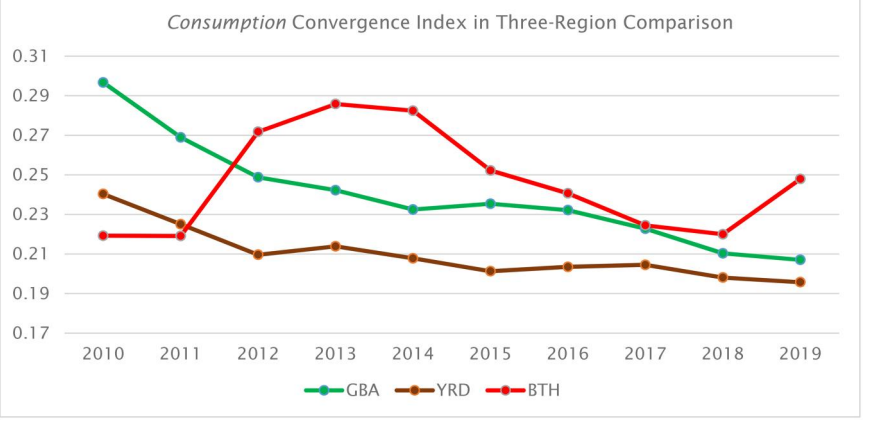

Figure 12. Consumption convergence index in three-region comparison.

Figure 12 shows the convergence in the *Consumption* dimension, where cities in the GBA made the most significant and quickest convergence compared to other dimensions or regions. In contrast, the converge index for BTH varies substantially in the period, showing large divergence in 2012–2015. As a result, despite starting at a level of dispersion far above that in BTH, the cities in the GBA became much more similar in this dimension than those in BTH at the end of the period. Cities in YRD exhibit the same pattern as that in GBA, converging considerably in the period.

GBA cities also display significant convergence in *Human Capital* dimension compared to YRD and BTH, as shown in Figure 13. The convergence indices of YRD and BTH fluctuate substantially in the period and end up slightly smaller at the end of the period.

As mentioned in Section 2, data on the contributions of various industries to GDP are not available for several cities in YRD and BTH. Therefore, when comparing convergence in the diversification dimension, the diversification index is calculated based on three-sector data for all three megalopolises. The results of the three-region

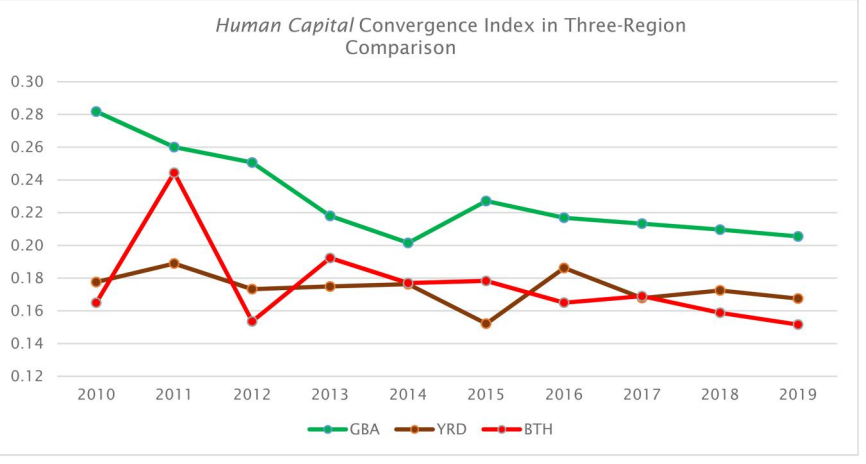

Figure 13. Human capital convergence index in three-region comparison.

comparison of the convergence in the diversification and the overall Economic Progress Index are included in Appendix A.

4.5. Discussion of policy initiatives to further integrate Hong Kong and Macao into the Greater Bay Area

The economic system of Hong Kong and Macao, owing to their colonial past, is different from that in the nine mainland GBA cities. The economies of the two SARs are characterized by low taxation, low government intervention, and free international trade. The two SARs enjoy a high degree of autonomy in economic, trade, financial, and monetary matters while retaining a separate immigration and custom control from the mainland. There is no central bank in either economy and their currencies, the Hong Kong dollar and Macao pataca, are pegged against the US dollars. Hong Kong, a former British colony, is a major international financial center; it also exhibits its strength other service areas, such as tourism, trading and logistics, and professional and producer services. Macao, a former Portuguese colony, is the largest gambling hub in the world and relies on the exports of gaming and tourism services as the main economic drive.

The differences in the economic systems between Hong Kong and Macao and the mainland GBA cities manifest themselves into disparities in some indicators in the *macro* and *openness* dimensions as discussed above. However, the SARs' characteristics – for example, Hong Kong's strength in financial services – can also be leveraged to promote their economic integration with the mainland GBA cities as well as faster progress of the whole GBA. First, Hong Kong and Macao already have very strong economic linkage with the mainland. The mainland is the largest trade partner of Hong Kong and Macao, supplying variety of goods, including raw material, energy, and food products, to Hong Kong and Macao. In 2021, Hong Kong was the mainland's largest source of realized FDI, accounting for about 54.7% of the national total. Most of these investments concentrate in the Guangdong province.[14] Macao's

economy thrives on inflows of tourists for its hospitality and gaming industries; most of the tourists come from the mainland.

Second, there are several policy initiatives, including the GBA development plan itself, from the central and local governments to further integrate Hong Kong and Macao into the mainland. One focus of the policies is to significantly raise the cross-border flows of financial services. For example, the Northbound Bond Connect, launched in July 2017, is a channel for overseas investors to access the mainland bond market through Hong Kong whereas the Southbound Bond Connect, launched in September 2021, provides mainland investors a means to purchase foreign debt securities through Hong Kong bond market. In September 2021, GBA Wealth Management Connect, a key initiative under the mutual market access scheme between the capital markets of Hong Kong, Macao, and the mainland, took effect. It is a closed-loop capital flow arrangement allowing residents in the GBA cities to invest in wealth management products issued in the region. Its purpose is to promote cross-border financial flows, investment options, and the use of RMB.

As part of the central government's support for Macao's diversification into financial services and other industries, some large state-owned enterprises and government agencies have also issued RMB-denominated bonds in Macao in the last several years. The Guangdong-Macao In-Depth Cooperation Zone in Hengqin, the largest island in Zhuhai, was created in 2021 to facilitate Macao's foray into scientific research, traditional Chinese medicine, financial services as well faster development in Meetings, Incentives, Conventions, and Exhibitions (MICE). The zone also provides space for Macao residents to live and work with a preferential income tax treatment.

Another focus of the government support is to enhance the transportation networks in the region to further promote cross-border flows of people. Hong Kong – Zhuhai – Macao bridge, a 55-kilometer bridge-tunnel system, was completed in 2018 to ease border-crossing between the two SARs with the mainland. Although Hong Kong had already had a rail line carrying daily commuters between itself and Shenzhen, the Hong Kong section of the Guangzhou-Shenzhen-Hong Kong high-speed railway entered service in September 2018. This new transport option provides faster and more convenient commute as it allows the passengers to clear the custom procedure in advance in either Shenzhen or Hong Kong. Macao is planning to extend its light rail transit system into Hengqin. A new 24-h port and custom checkpoint between Macao and Hengqin was also opened along with the creation of the Guangdong-Macao In-Depth Cooperation Zone.

5. Concluding remarks

In this study, we employ principal component analysis (PCA) to provide three composite index measures of the economic development of eleven cities in the Guangdong – Hong Kong – Macao Greater Bay Area (GBA) for the period of 2010–2019. The Economic Progress Index (EPI) consists of sixteen socio-economic indicators spanning five dimensions of macro, openness, consumption, human capital, and diversification. The EPI is constructed to track the progress individual cities make along these dimensions. The Economic Diversification Index (EDI), which itself

represents the dimension of economic diversity in the EPI, is based on GDP shares of different industries in each GBA city. The EDI is used to show the economic diversity of each city. The Economic Convergence Index (ECI), a sigma-convergence measure of disparities, is computed to track the process of convergence among the GBA cities in the above five dimensions. The aims of these indices are to facilitate a better understanding of the development of this region and to identify specific areas that need improvement or policy support.

The results show that the GBA made significant progress in all five dimensions. Persistent high economic growth, supported by high investment rate and fiscal spending, raised per capita GDP and average employment earnings in the region by about 60 and 100%, respectively. Economic welfare and human capital rose considerably in the sample period. At the same time, the region went through a structural transformation in which the regional economies moved away from manufacturing of export goods and toward services. Because of this shift, the region as whole became more diversified. The GBA also become more similar in terms of human capital and economic welfare.

Although located geographically close to one another, the eleven GBA cities still differ substantially in some economic dimensions. This represents both challenges and opportunities for the policy makers and stakeholders in the region. Challenges arise because besides general policies implemented to move the region uniformly in some directions, some policies must be designed to target a particular aspect of development in a specific city. For example, incentives and support should be provided to Foshan and Dongguan to encourage diversification into other industries other than manufacturing. Entirely different policies, however, must be applied to Macao to reduce its reliance on gaming services while maintaining the role of the service sector in the economy as there is no longer any economic basis for Macao to revive its former manufacturing base.

There are also opportunities. Take openness as an example. Given the wide disparity in this dimension yet proximity among the cities provides a huge scope for cooperation among the cities to attract foreign direct investment, promote exports, and propagate the regional supply chain to other smaller and less open economies. Moreover, the robust existing supply networks in goods and export commodities can be leveraged to open another front in the service networks as well.

The diversification index for each city is calculated based on the GDP contributions of primary, secondary, and tertiary sectors. Then the convergence index is computed for each megalopolis. The results are shown in Figure A1. Based on this set of more aggregate sector data, it appears no convergence in the economic diversification dimension was made for the cities in GBA and YRD, while those in BTH exhibit some divergence in the period.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Acknowledgements

We thank Chi-shing Chan for the helpful discussion and assistance with some data work.

Notes

1. The other two first-tier cities are Beijing and Shanghai. In some classifications, Chongqing is also considered a first-tier city.
2. See https://www.bayarea.gov.hk/en/about/overview.html.
3. Organization for Economic Co-Operation and Development (OECD) published a guide to the construction and use of composite indicators. See OECD (2008).
4. Although the two Special Administrative Regions (SARs) of Hong Kong and Macao maintain separate immigration and custom controls from those in the mainland, the local residents of the SARs can travel freely to the mainland. It is also simple for the residents of the mainland GBA cities to travel to the two SARs for work and tourism. Many people, indeed, live in the nearby mainland cities and commute daily to work in the two SARs.
5. https://www.dsec.gov.mo/en-US/Home/Publication/MacaoInFigures
6. Manufacturing and other secondary industries are considered in the Economic Diversification Index, which itself constitute the *Diversification* dimension.
7. The large gap between GDP per capita and median earnings arises because the casino industry is the dominant contributor to Macao's GDP; the majority of the output in this industry accrues to a few local and, particularly, international casino license holders.
8. Ideally, only households' electricity consumption, instead of overall consumption in each city, should be used; however, this information is not available for all the cities.
9. There are no city-level data for adult literacy and life expectancy in China. Moreover, as the nine mainland GBA cities are located next to one another while sharing cultural values and habits, including diets, the residents are likely to have similar life expectancy.
10. Provincial government of Guangdong: http://stats.gd.gov.cn/gdtjnj/index.html
    Government of Hong Kong SAR: https://www.censtatd.gov.hk/
    Government of Macao SAR: https://www.dsec.gov.mo/
    The World Bank: https://data.worldbank.org/
11. As an example, suppose per capita GDP accounts for very large weight compared to the other four indicators and the *Macro* dimension dominates the other four dimensions. Then the composite EPI is driven primarily by a single indicator, per capita GDP here, thereby negating the need to construct a composite index in the first place. In addition, the EPI value for Macao would be much higher than the rest of GBA cities, reflecting the fact that Macao's per capita GDP in 2019 was among the highest in the world and many times that of the rest of the GBA.
12. See "GBA head pledge enhanced partnership in science, tech" in China Daily (chinadaily.com.cn) on May 21, 2023.
13. Cross-city averages are weighted averages in which the weights are either the population or GDP of the cities.
14. https://www.tid.gov.hk/english/aboutus/publications/factsheet/china.html

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Appendix A

Table A1. Weights of indicators in the dimensions.

Macro	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010
GDP per capita	0.210	0.193	0.203	0.212	0.225	0.200	0.203	0.204	0.206	0.204
GDP growth	0.185	0.155	0.203	0.199	0.201	0.211	0.214	0.219	0.211	0.210
Services	0.216	0.229	0.202	0.211	0.210	0.212	0.209	0.212	0.204	0.203
Investment	0.158	0.185	0.187	0.163	0.158	0.153	0.163	0.163	0.168	0.177
Government spending	0.229	0.238	0.206	0.216	0.207	0.225	0.211	0.203	0.211	0.206
Openness										
Trade	0.333	0.329	0.329	0.329	0.329	0.327	0.325	0.325	0.323	0.321
FDI	0.331	0.329	0.329	0.329	0.329	0.327	0.325	0.324	0.323	0.319
Tourists	0.337	0.342	0.342	0.341	0.343	0.345	0.350	0.351	0.354	0.361
Consumption										
Price stability	0.371	0.318	0.320	0.326	0.327	0.323	0.321	0.310	0.326	0.333
Median earnings	0.261	0.305	0.319	0.327	0.327	0.323	0.322	0.305	0.312	0.292
Energy consumption	0.368	0.377	0.361	0.347	0.346	0.353	0.357	0.385	0.363	0.375
Human capital										
Teacher-student ratio	0.283	0.289	0.298	0.281	0.284	0.266	0.265	0.246	0.259	0.259
Health and education	0.195	0.209	0.181	0.206	0.214	0.204	0.239	0.262	0.262	0.277
Hospital beds	0.221	0.210	0.217	0.220	0.217	0.241	0.226	0.247	0.240	0.248
Doctors	0.300	0.292	0.304	0.292	0.285	0.289	0.270	0.245	0.238	0.216

Table A2. Weights of the dimensions in the economic progress index.

	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010
Macro	0.209	0.205	0.198	0.204	0.210	0.208	0.202	0.204	0.202	0.202
Openness	0.210	0.195	0.163	0.167	0.174	0.189	0.186	0.186	0.187	0.191
Consumption	0.193	0.215	0.208	0.220	0.216	0.207	0.202	0.205	0.203	0.203
Human capital	0.174	0.196	0.202	0.186	0.182	0.183	0.195	0.190	0.190	0.196
Diversification	0.214	0.189	0.229	0.224	0.219	0.213	0.215	0.215	0.217	0.208

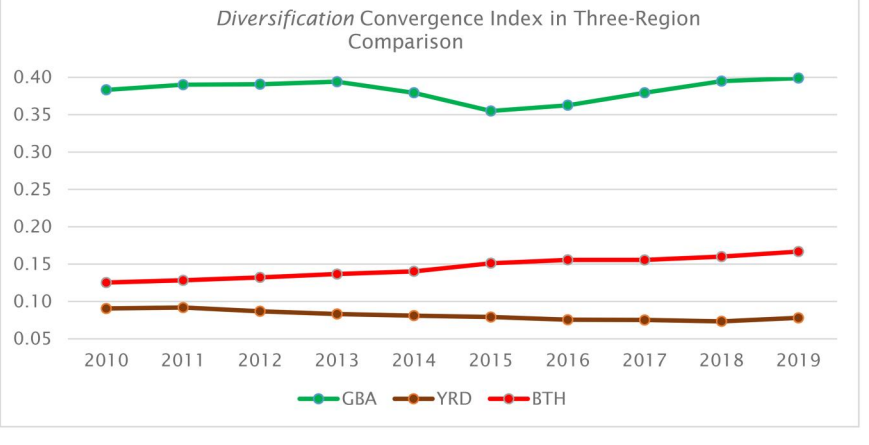

Figure A1. Diversification convergence index in three-region comparison.

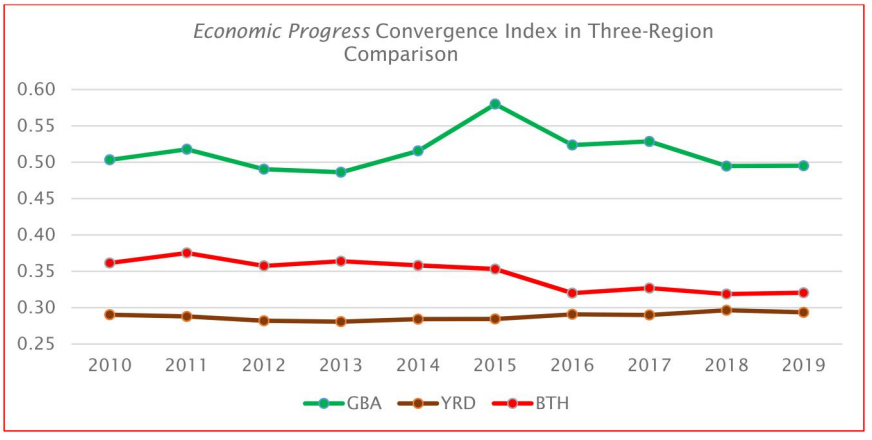

Figure A2. Economic progress convergence index in three-region comparison.