

# An empirical study on the correlation between university discipline and industrial structure in the Guangdong, Hong Kong, and Macao greater bay area

An empirical study on the greater bay area

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## Abstract

**Purpose** – This paper examines the correlation between university discipline and industrial structure in the context of the integration and development of the Guangdong-Hong Kong-Macau Greater Bay Area (hereinafter the Greater Bay Area). It aims to determine the industrial structure deviation, and further identify human resource shortages and complementarity through the lens of the university discipline layout in the three regions of the Greater Bay Area, namely, the nine mainland Guangdong cities in the Pearl River Delta, Hong Kong, and Macau.

**Design/methodology/approach** – The paper takes a quantitative Pearson correlation approach to determine the magnitude and strength of the relationship between regional university discipline and industrial structure in the Greater Bay Area, using predictor variables of percentage of compositions of GDP by sector to manifest the industrial structure and criterion variables of percentage of compositions of university enrollments by an academic program to represent the university discipline layout.

**Findings** – The most significant empirical result suggests that industrial structure deviation exists in the secondary industries of both Guangdong and Hong Kong. This indicates the complementarity between regions of the Greater Bay Area: the number of science and engineering talents graduating from the universities in Hong Kong exceeds the demands of Hong Kong's local needs, while the science and engineering talents cultivated by universities in Guangdong cannot satisfy the needs of its secondary industries. However, the cities of Guangdong are not the primary choice of most Hong Kong graduates (Zhaopin, 2019).

**Originality/value** – There have been previous empirical studies dealing with the correlation between Chinese higher education discipline layout and industrial structure at the national level. There have been more case analyses at the provincial level, and some studies have used a comparative lens to find implications for the Chinese transformation. However, few studies have examined the correlation between higher education discipline layout and industrial structure in the context of the Greater Bay Area, with its emphasis on regional synergy and the distinction of "one country, two systems, and three tariff zones." Based on its empirical



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findings, this study calls for a talent ecosystem that is beneficial for talent flow, talent sharing, and talent cultivation in a complementary manner.

**Keywords** Correlation analysis, University discipline, Industrial structure, The Guangdong-Hong Kong-Macao Greater bay area

**Paper type** Research paper

## 1. Introduction

*The Outline Development Plan of Guangdong, Hong Kong and Macao Greater Bay Area* (the “Plan”) was issued by China’s central government in February, 2019. It has been formulated to strengthen regional synergy through fully leveraging the composite advantages of Guangdong, Hong Kong, and Macao on all-important aspects of economic development, with a distinct principle of “one country, two systems” (Jie et al., 2019). The key concept of the Greater Bay Area proposed by China’s central government is encapsulated in the term “Guangdong—Hong Kong—Macao” rather than the term “Bay Area”; the Plan outlines regional integration, cooperation mechanism innovation, cooperation platform construction, and cross-boundary institutional development (Chen and Lin, 2018).

This paper takes a quantitative Pearson correlation approach to examine the correlation between university discipline and industrial structure in the context of regional integration in the Greater Bay Area (the GBA). It aims to determine the industrial structure deviation, and further identify human resource shortages and complementarity through the lens of university discipline layout in the three regions of the GBA, namely, nine mainland Guangdong cities in the Pearl River Delta, Hong Kong, and Macau.

The *Plan* proposes to shape the GBA into a “Talent Bay Area” (Fitzsimons, 2017). Experience of world-class international bay areas shows that the accumulation of innovative and entrepreneurial talents is a key driving force for regional economic development (Xiao, 2009). According to human capital theory, human capital, namely, talents, provide intellectual support for upgrading industrial structure. The competence, type, and quantity of the talents determine the speed of the upgrade (Cui, 2015).

In the era of the knowledge economy, a fundamental role of higher education demonstrates its correlation with economic development through human capital development and technology diffusion (Sirbu, 2015). As a significant part of the economic structure, the industrial structure reflects the latitude and trends of regional and national economic development. The adjustment of the industrial structure will inevitably bring about changes to the social employment structure, which will, in turn, affect the demands for human resources in different fields (Lenihan et al., 2019).

Cultivating the talents needed for industrial transformation is a basic function of higher education. A regional university discipline structure directly affects the talent structure of various industrial sectors in the region. Only when the above-mentioned two elements are adapted to each other, can regional higher education resources be scientifically allocated. The regional economic development of the GBA has raised challenges and demands for corresponding support from regional higher education (Xiao, 2009).

However, little is known about the interrelationship between regional higher education and economic development in the GBA. This study aimed to enrich the knowledge about this correlation with a specific focus on regional higher education integration. Therefore, the research questions were: What are the correlations between regional university discipline layout and industrial structure in the GBA? And what kind of implications can be provided for regional talent flow and sharing?

The remainder of this paper is organized as follows: the next section introduces the literature dealing with the correlation between the Chinese higher education discipline layout and the industrial structure at national and provincial levels, as well as studies using

comparative and international lenses. This section is followed by an elaboration of the methodology used in this study, including assumptions, data collection and analysis. The fourth section is a presentation of the results and findings based on correlation analysis; limitations of the study are also presented. The last section concludes with major implications for policy-makers and other stakeholders, highlighting the creation of a talent ecosystem in the GBA for cross-border integration in a complementary, efficient and sustainable manner.

## 2. Literature review

### 2.1 National, regional and provincial analysis

Cui (2015) used the *Autoregressive Distributed Lag Model* to find out that there is a significant long-term equilibrium relationship between the enrollment ratio of most Chinese university disciplines and the industrial employment structure, except for the discipline of literature. Yang *et al.* (2015) used the *Euclidean Distance Coordination Model* and found that the structural adjustment of China's university disciplines lags behind the actual needs of industrial structure upgrading. Guo's (2014) research emphasized that regional higher education needs to be organized based on the regional industrial structure. The super-structure design of higher education should take account of the regional complementarity of disciplines, professions and levels from a perspective of regional integration.

Tang *et al.* (2015) and Wang and Li (2018) used the *Grey Relational Analysis Model* to analyze the undergraduate universities of Guangdong. Wu and Zeng (2015) analyzed the adaptation path and influence degree in Jiangxi Province from 1999 to 2012, using *Canonical Correlation Analysis, Factor Analysis and Regression Analysis*. Lei (2017) looked into the case of Liaoning Province from 2006 to 2015, while Wang and Wang (2017) took Sichuan Province from 2005 to 2014 as their unit of analysis.

### 2.2 International case analysis

In general, there is a lack of literature in the English language featuring such correlation analysis. One reasonable explanation is that university discipline classification in China is strong, and the disciplinary boundaries are clear, whereas, in the case of countries such as the USA, the university discipline organization is much more open (Li and Xie, 2011). However, there are some studies on international cases in the Chinese language, such as Wang *et al.* (2016) taking the case of the USA, and Liu and Wang (2016) taking the cases of the USA, UK and Japan from a historical perspective.

In summary, there have been empirical studies dealing with the correlation between Chinese higher education discipline layout and industrial structure at the national, regional, and provincial levels and some studies have used a comparative lens to find implications for the Chinese transformation. However, few studies have examined the correlation between university discipline layout and industrial structure in the context of the GBA, with its emphasis on regional synergy and the distinction of "one country, two systems, and three tariff zones."

## 3. Methodology

This study centered on the correlation between regional university discipline layout and industrial structure in the GBA. A quantitative approach was employed based on the following qualitative interpretation:

The industrial structure is an important indicator of changes in social demand; in particular, it is the most salient indicator of social demand for different kinds and layers of labor.

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First, industrial structure influences university discipline structure through the factors of employment and wages; second, changes in labor demand result in the emergence of new disciplines and the demise of outdated ones; third, indirect social, environmental variables, as intermediate factors of industrial structure, can also bring changes to a university discipline structure (Cui, 2015).

On the other hand, university discipline structure affects industrial structure mainly through the supply of human capital: first, in a regional context, if the number of university graduates in a certain discipline exceeds the need of the corresponding industrial sector, this may result in a waste of human resources, and conversely, an insufficient supply of talents will be harmful to the sustainable development of that sector; second, the quality of university graduates also has an impact on corresponding industrial development; third, the proportion of graduates with bachelor's, master's and doctoral degrees is also related to the needs of industry, and greatly affects the growth of industrial sectors (Xin, 2016).

The data analysis in this study was performed using Pearson's correlation, which has a small standard error (Gall *et al.*, 2005) and is appropriate for interpreting phenomena in educational contexts (Martella *et al.*, 2013). The predictor variables were percentage of compositions of GDP by sector, manifesting the industrial structure, while the criterion variables were percentage of compositions of university enrollments by academic programs, representing university discipline layout.

To increase the credibility and validity of the study, we analyzed the correlation between university discipline and industrial structure layout in Guangdong, Hong Kong and Macao separately due to: (1) the duration availability of original data was different; (2) the university discipline classification in the Chinese Mainland has strong and clear boundaries (Qiong and Qin, 2019), while the boundaries of universities disciplines in Hong Kong and Macao are vaguer; (3) technically, the statistical standards of higher education and industry in the three regions are different.

### 3.1 Assumptions

**3.1.1 Guangdong.** There is a statistically significant relationship between the percentage of composition of primary/secondary/tertiary sector GDP and the percentage of composition of university enrollment in corresponding disciplines in Guangdong.

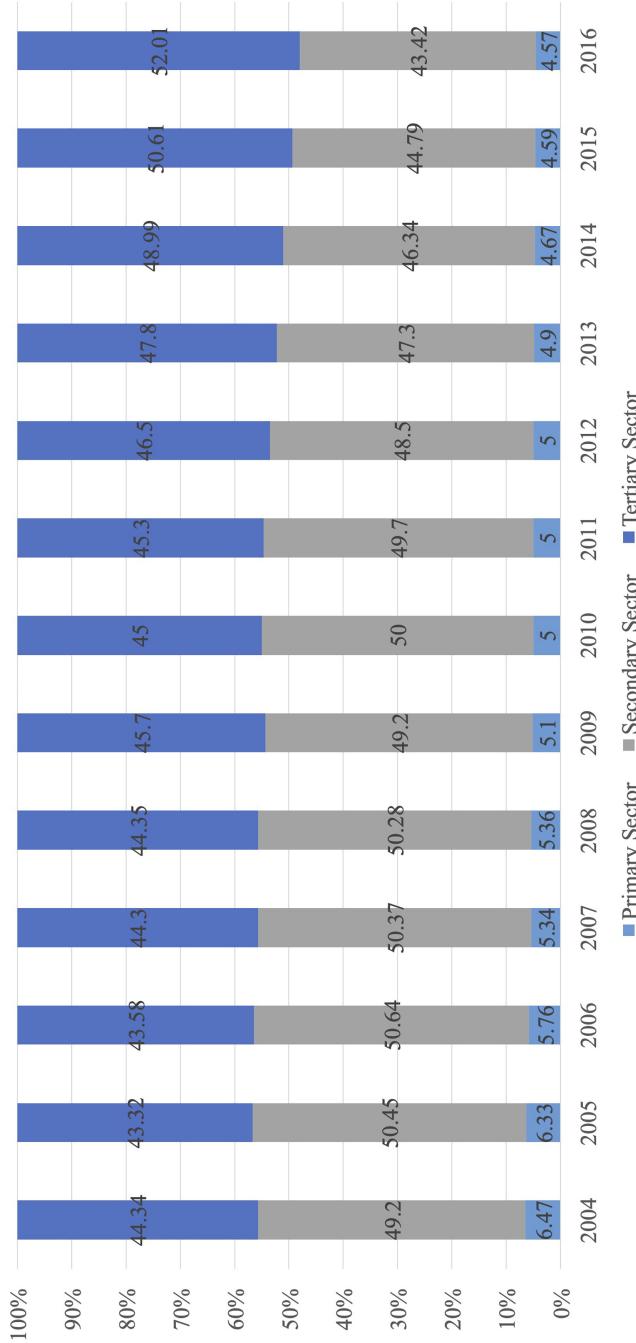
**3.1.2 Hong Kong and Macao [1].** There is a statistically significant relationship between the percentage of composition of secondary/tertiary sector GDP and the percentage of composition of university enrollment in corresponding disciplines in Hong Kong/Macao.

### 3.2 Data collection

Above all, this study followed the same classification of industries and corresponding disciplines to ensure the comparability of the three regions. Specifically, the primary sector includes agriculture and fishing, and the corresponding discipline is agronomy; secondary sector includes industry, mining and quarrying, manufacturing, electricity, gas and water supply, waste management, construction and the corresponding disciplines are science and engineering; tertiary sector includes all services industries, and the corresponding disciplines are medicine, economics, business and management studies, social sciences, law, arts and humanities, education, philosophy, history, personal services.

To further ensure the reliability of results, credible and consistent data sources were selected for each data category. Three periods, 2004–2016, 1993–2016, 2003–2017, were chosen for Guangdong, Hong Kong and Macao, respectively, as a result of the availability of data. Guangdong's compositions of GDP by industry from 2004 to 2016 were accessed from the National Bureau of Statistics of China in the Wind Economic Database (See Figure 1). Compositions of GDP by industry in Hong Kong from 1993 to 2016 were gathered from the

Percent Composition of GDP by Industry (Guangdong)



Source(s): The National Bureau of Statistics of China in the Wind Economic Database

**Figure 1.**  
Percentage of  
composition of GDP by  
industry (Guangdong)

“Percentage contribution to Gross Domestic Product by economic activity” section of the *Hong Kong Annual Digest of Statistics (1994–2017)* (See [Figure 2](#)). As for Macao, the percentage of compositions of GDP by industry from 2003 to 2017 were calculated by the authors based on data collected from the Statistics and Census Bureau of Macau in the Wind Economic Database (See [Figure 3](#)).

Second, percentage of compositions of university enrollment by discipline in Guangdong from 2004 to 2016 were directly extracted from the *Guangdong Education Yearbook (2005–2017)* (See [Figure 4](#)). For Hong Kong, the percentage of compositions of UGC-funded university enrollment by discipline from 1993 to 2016 were calculated based on data from the “Enrollment in UGC-funded university by academic programs” section of the *Hong Kong Annual Digest of Statistics (1994–2017)* (See [Figure 5](#)). Finally, the percentage of compositions of university enrollment by discipline from 2003 to 2017 were also calculated for Macao based on the “Students Enrolled in Higher Education” section of the *Macao Yearbook of Statistics (2003–2017)* (See [Figure 6](#)).

### *3.3 Correlation analysis*

For a beginning, the magnitude and significance of the correlation of percentage of composition of GDP by industry and percentage of composition of university enrollment by discipline were considered to be useful in that the two variables indicated the industrial structure and university discipline layout in the GBA, respectively. This allowed the authors to analyze the advantages and problems of the university discipline settings from the perspective of industry structure. Moreover, the two variables of interest were measured using ratio scales and met the assumptions of normal distribution and linearity ([Martella et al., 2013](#)) essential for applying Pearson correlation analysis.

In addition, after the assumption tests underlying the Pearson correlation had been carried out with a *p*-value of less than 0.05 to confirm their validity, the value of the correlation coefficient (*r*) could be interpreted with some degree of confidence

While the sign of an *r* value indicates whether the direction of a relationship between two variables is either positive or negative, the absolute value of *r* indicates the magnitude and strength of the relationship. When the absolute value of *r* is closer to 1.00, the interrelation between the two variables is stronger. This study utilized SAS University Edition software to support correlation analysis of the variables.

Last but not least, the null hypotheses developed on the basis of the assumptions in this study were as follow:

*H1/H2/H3.* There is no statistically significant relationship between the percentage of composition of primary/secondary/tertiary sector GDP and the percentage of composition of university enrollment for corresponding disciplines in Guangdong.

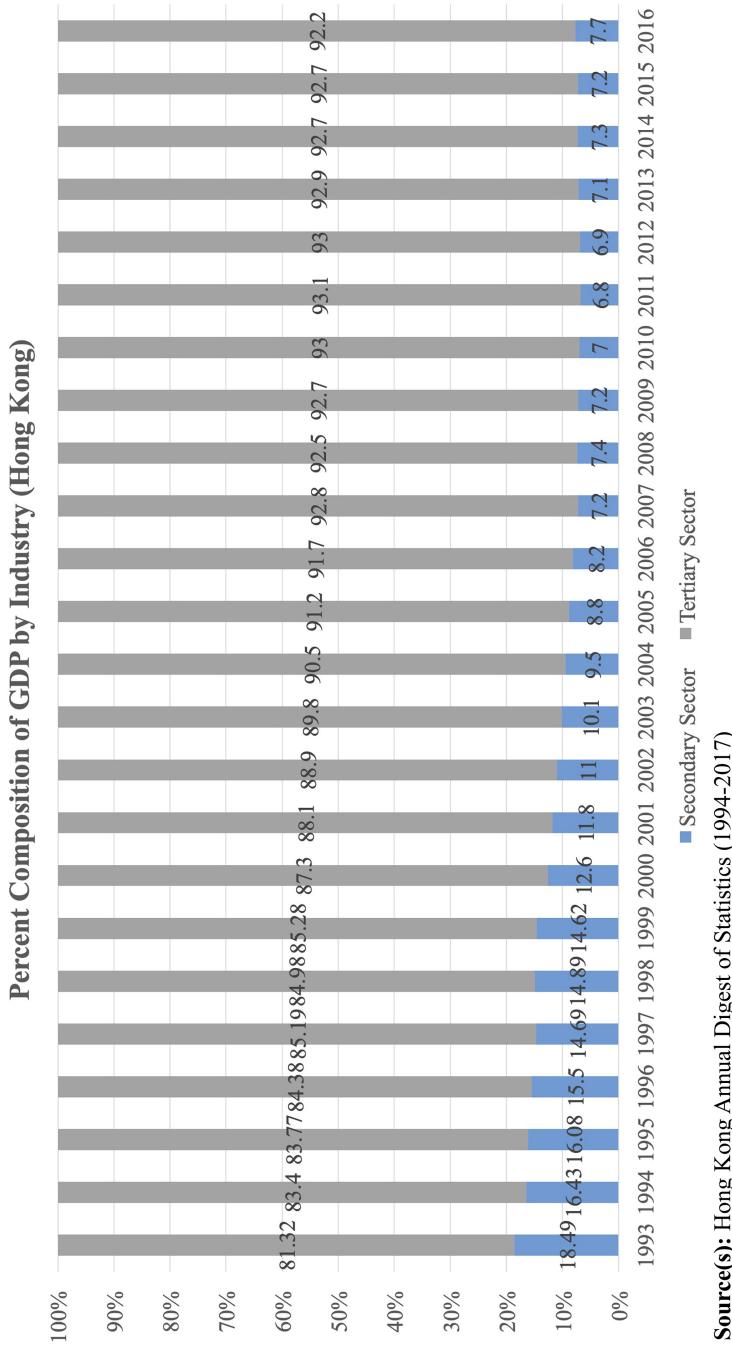
*H4/H5.* There is no statistically significant relationship between the percentage of composition of secondary/tertiary sector GDP and the percentage of composition of university enrollment for corresponding disciplines in Hong Kong.

*H6/H7.* There is no statistically significant relationship between the percentage of composition of secondary/tertiary sector GDP and the percentage of composition of university enrollment for corresponding disciplines in Macao.

## **4. Results and findings**

### *4.1 Results*

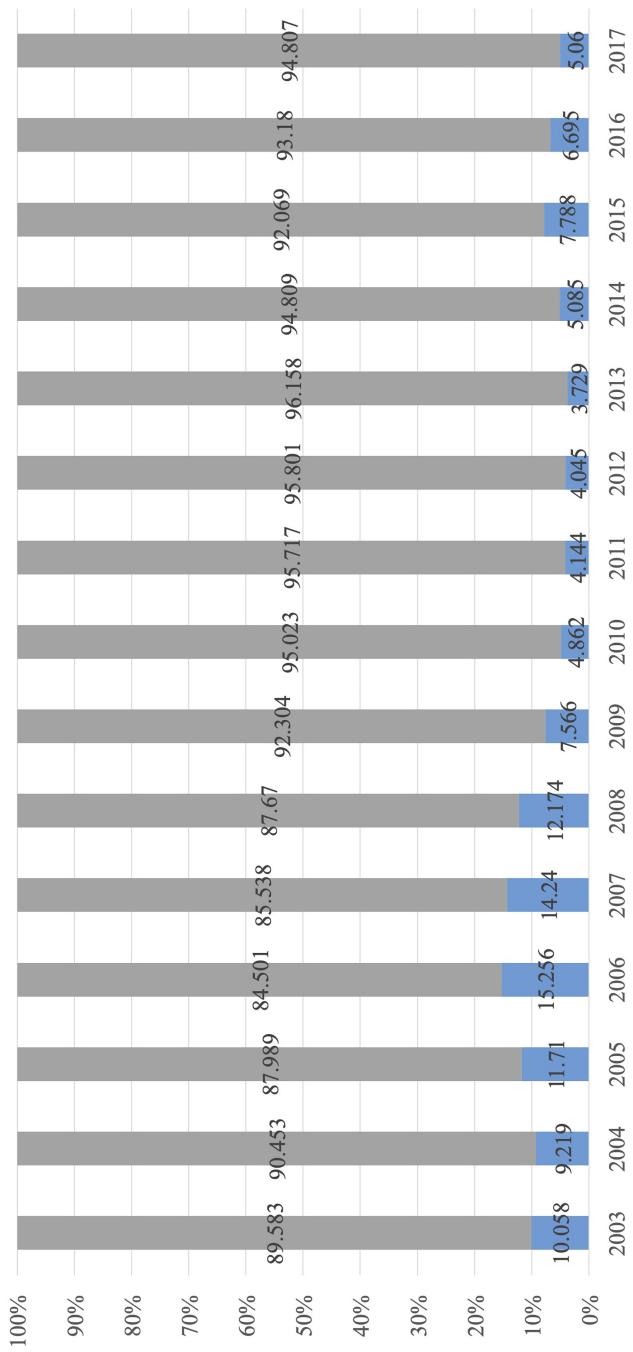
*4.1.1 Guangdong.* The percentage of composition of primary sector GDP and the percentage of composition of university enrollments for the corresponding discipline, namely Agronomy,



**Figure 2.**  
Percentage of  
composition of GDP by  
industry (Hong Kong)

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**Figure 3.**  
Percentage of  
composition of GDP by  
industry (Macau)



**Source(s):** Authors' own calculation based on data retrieved from the Statistics and Census Bureau of Macau in the Wind Economic Database

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Composition of Enrollments in Universities by Discipline (Guangdong)										Percentage	
Year	Agronomy	Corresponding Disciplines of Primary Sector			Corresponding Disciplines of Secondary Sector						Total
		Science	Engineering	Total	Philosophy	Economics & Management Studies	Law	Education	Humanities & Arts	History	
2004	1.34	6.1	29.92	36.02	0.04	29.67	4.27	5.84	15.65	0.3	6.86
2005	1.41	5.64	30.32	35.96	0.03	28.31	4.53	7.22	14.93	0.3	7.31
2006	1.27	5.27	30.04	35.31	0.03	29.79	4.42	6.25	15.43	0.29	7.19
2007	1.13	5.26	29.82	35.08	0.04	31.23	4.13	5.59	15.65	0.3	6.86
2008	1.04	5.24	29.54	34.78	0.04	32.29	3.92	5.29	15.92	0.3	6.43
2009	0.99	5.18	29.71	34.89	0.04	32.67	3.76	5.29	15.69	0.31	6.36
2010	0.98	5.34	29.85	35.19	0.04	32.66	3.53	5.31	15.68	0.32	6.29
2011	1.36	9.79	24.15	33.94	0.07	31.02	4.53	3.31	17.61	0.55	7.63
2012	1.38	9.46	24.61	34.07	0.06	31.46	4.3	3.24	17.68	0.52	7.29
2013	1.39	7.45	26.53	33.98	0.06	32.13	4.18	2.76	18.11	0.48	6.91
2014	1.41	7.2	26.64	33.84	0.06	32.33	4.16	2.69	18.32	0.46	6.73
2015	1.44	7.01	26.89	33.9	0.06	32.63	4.12	2.64	18.41	0.44	6.36
2016	1.38	6.84	27.63	34.47	0.07	32.26	4	2.57	18.53	0.42	6.3
											64.15

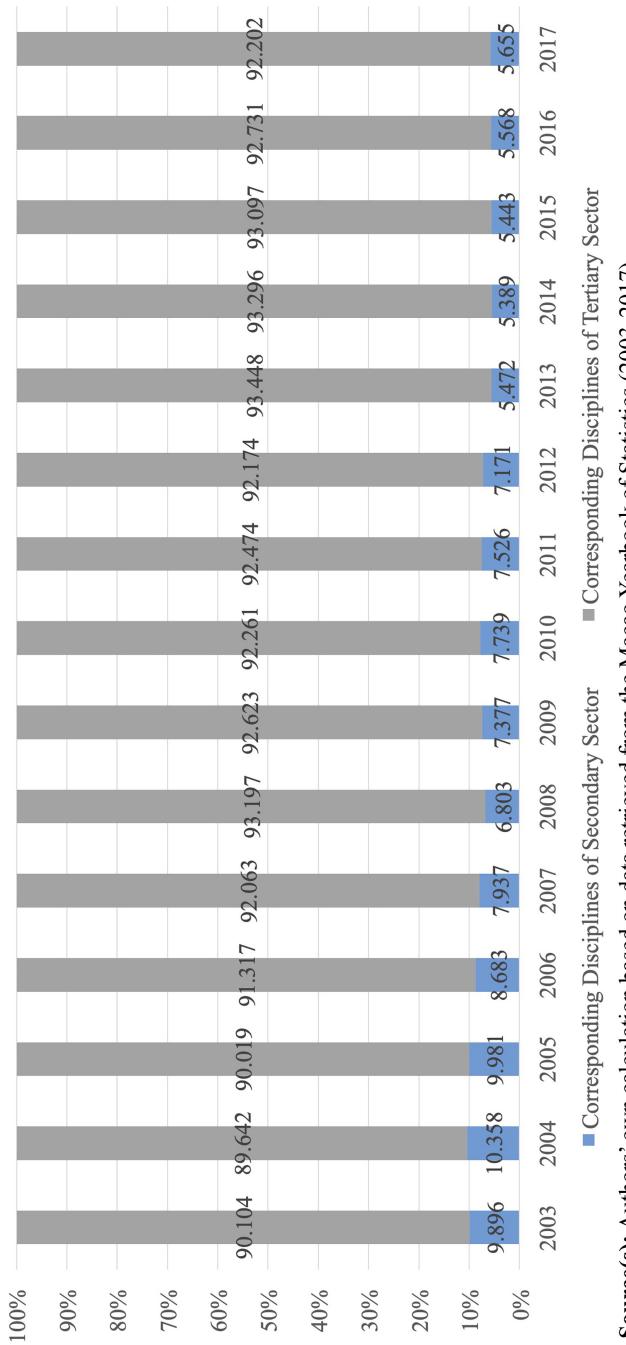
Source(s): Guangdong Education Yearbook (2005-2017)

**Figure 4.**  
Composition of enrollments in universities by Discipline (Guangdong)

Year	Corresponding Disciplines of Secondary Sector		Corresponding Disciplines of Tertiary Sector						Percentage
	Science	Engineering	Total	Business & Management Studies	Law	Social Sciences	Humanities & Arts	Education	
1993	19.49	25.60	45.09	21.81	N/A	11.73	11.23	4.16	5.98
1994	19.81	24.19	44.00	22.27	N/A	11.07	11.99	4.69	5.98
1995	17.94	21.79	39.73	26.84	1.84	9.18	11.67	4.52	6.22
1996	16.49	20.37	36.86	24.66	1.70	8.66	14.53	7.72	5.86
1997	16.40	19.99	36.39	24.58	1.70	8.19	14.86	7.96	6.31
1998	16.30	19.85	36.14	23.90	1.59	8.23	14.96	8.41	6.78
1999	16.22	19.33	35.55	23.13	1.56	8.31	15.64	8.88	6.93
2000	16.23	19.31	35.54	22.58	1.56	8.58	15.99	8.87	6.88
2001	16.98	19.77	36.75	22.28	1.61	8.56	14.84	8.99	6.95
2002	17.20	19.27	36.46	19.43	1.60	10.66	14.75	10.10	7.00
2003	16.80	19.28	36.08	19.07	1.48	10.72	15.57	10.00	7.09
2004	16.77	19.02	35.80	18.90	1.23	10.38	15.61	10.38	7.70
2005	16.86	19.51	36.37	18.72	1.28	10.47	15.93	8.89	8.33
2006	16.71	19.82	36.53	18.66	1.34	9.83	15.74	9.05	8.86
2007	16.26	20.05	36.31	18.94	1.59	9.38	15.23	9.45	9.11
2008	16.10	19.96	36.06	19.19	1.69	9.40	15.45	9.20	9.01
2009	16.08	19.94	36.02	19.11	1.77	9.25	15.28	9.43	9.14
2010	16.33	19.65	35.98	18.80	1.76	9.34	14.79	9.94	9.39
2011	16.17	19.90	36.07	18.50	1.77	9.20	14.67	10.04	9.75
2012	16.71	19.12	35.83	18.35	1.73	9.58	14.99	9.16	10.43
2013	17.08	18.37	35.44	17.87	1.72	9.94	16.70	8.81	10.56
2014	16.15	19.37	35.52	18.59	1.69	10.17	14.64	8.78	10.61
2015	16.09	19.54	35.63	18.54	1.68	10.20	14.86	8.63	10.47
2016	16.34	19.67	36.01	18.52	1.67	10.18	14.67	8.14	10.81

**Sources:** Authors' own calculation based on data retrieved from the Hong Kong Annual Digest of Statistics

Percent Composition of Enrollments in Universities by Discipline (Macao)



Source(s): Authors' own calculation based on data retrieved from the Macao Yearbook of Statistics (2003-2017)

**Figure 6.**  
Percentage of  
composition of  
enrollments in  
universities by  
discipline (Macao)

were not significantly correlated. Therefore, H<sub>1</sub> was accepted. The other two sectors, however, exhibited a positive correlation when the researchers took their corresponding disciplines as a whole (see Table 1). In this case, H<sub>2</sub> and H<sub>3</sub> were rejected. More precisely, the strength of the correlation between the secondary sector GDP and corresponding disciplines'

Correlations of percentage of compositions of GDP for the sector and corresponding discipline(s) in <i>Guangdong</i>	<i>r</i>	<i>p</i> -value	Significant (0.05 level)	Strength	Positive or negative
Primary sector and Agronomy	-0.03648	0.9058	No		
Secondary sector and all corresponding disciplines	0.57571	0.0395	Yes	Moderate	Positive
Science	-0.31929	0.2876	No		
Engineering	0.43446	0.1379	No		
Tertiary sector and all corresponding disciplines	0.60081	0.0299	Yes	Strong	Positive
Economics and management studies	0.59695	0.0312	Yes	Moderate	Positive
Medicine	-0.44998	0.1229	No		
Humanities	0.88351	<0.0001	Yes	Very strong	Positive
Law	0.19067	0.5327	No		
Philosophy	0.78079	0.0016	Yes	Strong	Positive
History	0.55748	0.0478	Yes	Moderate	Positive
Education	-0.85763	0.0002	Yes	Very strong	Negative

Correlations of percentage of compositions of GDP for the sector and corresponding discipline(s) in <i>Hong Kong</i>	<i>r</i>	<i>p</i> -value	Significant (0.05 level)	Strength	Positive or negative
Secondary sector and all corresponding disciplines	0.66433	0.000424	Yes	Strong	Positive
Science	0.61178	0.001524	Yes	Strong	Positive
Engineering	0.65839	0.000524	Yes	Strong	Positive
Tertiary sector and all corresponding disciplines	0.6745	0.000324	Yes	Strong	Positive
Economics and management studies	-0.87117	<0.000124	Yes	Very strong	Negative
Medicine	0.90146	<0.000124	Yes	Very strong	Positive
Humanities	0.63022	0.001024	Yes	Strong	Positive
Law	-0.01539	0.945822	No		
Social sciences	0.07687	0.721124	No		
Education	0.73366	<0.000124	Yes	Strong	Positive

Correlations of percentage of compositions of GDP for the sector and corresponding discipline(s) in <i>Macao</i>	<i>r</i>	<i>p</i> -value	Significant (0.05 level)	Strength	Positive or negative
Secondary sector and all corresponding disciplines	0.53561	0.0396	Yes	Moderate	Positive
Tertiary sector and all corresponding disciplines	0.45449	0.0888	No		

**Table 1.**  
Correlations of percentage of compositions of GDP for the primary/secondary/tertiary sector industry and percentage of compositions of university enrollments in the corresponding disciplines in *Guangdong/Hong Kong/Macao*

enrollments was moderate. Furthermore, if the corresponding disciplines of the secondary sector were divided into Science and Engineering, university enrollment for each discipline was even not significantly correlated with the secondary sector's GDP. Similarly, the disciplines corresponding to tertiary sector industries comprised seven individual disciplines. One of them (Humanities) demonstrated a very strong positive correlation, and two of them (Economics and management studies and History) were moderately and positively correlated, while the Education discipline exhibited a very strong negative correlation. In these circumstances, H3 was rejected for five disciplines but accepted for two disciplines.

*4.1.2 Hong Kong.* The percentage of composition of GDP, both for the secondary and tertiary sectors, was strongly and positively correlated with the percentage of composition of university enrollments in their corresponding disciplines as a whole (see Table 1). In particular, both corresponding disciplines in the secondary sector demonstrated a strong positive correlation. Thus, H04 was fully rejected. As for the corresponding disciplines in the tertiary sector, four of them exhibited a correlation, but two of them were not significantly correlated. Humanities and Education both showed a strong positive correlation. Medicine exhibited a very strong positive correlation, while Economics and business management studies unexpectedly indicated a very strong negative correlation. Overall, H5 was rejected for four disciplines and accepted for two disciplines.

*4.1.3 Macao.* A moderate positive correlation was found between correlations of percentage of compositions of GDP for secondary sector industries and percentage of compositions of university enrollments in corresponding disciplines. H6 was rejected. There was no significant correlation between the tertiary sector's GDP percentage of compositions and percentage of compositions of university enrollments in corresponding disciplines (see Table 1). Therefore, H7 was accepted.

## 4.2 Findings

*4.2.1 Guangdong.* Remarkably, the strength of the positive correlation between secondary sector GDP and enrolments in science and engineering was moderate, but it was strong between tertiary industries and their related disciplines (see Table 1). This was the opposite of the general situation. Moreover, when the researchers examined the science and engineering enrollments and secondary sector GDP individually, no correlation was found. On the other hand, there was a very strong positive correlation between humanities and arts and tertiary sector industries and a moderate one between economics and management studies and tertiary sector industries.

To some degree, this result echoes Yang et al.'s (2015) argument that the structural adjustment of China's higher education disciplines lags behind the actual needs of industrial structure upgrading, and the balance between science and engineering discipline and humanities disciplines needs to be strengthened. Furthermore, the tendency toward homogenization in the discipline layout is aggravating. In recent years, universities in Guangdong have been keen to establish disciplines with low entry requirements and low development costs that are specifically related to the service industry, including economics and management studies and humanities and arts (Dong and Wei, 2016).

It also indicates that graduates of certain disciplines corresponding to the tertiary sector surpass industry needs, while the supply of science and engineering talents lags behind market demand. This has been further affirmed by the report *Industry Development and Talent Flow in Guangdong-Hong Kong-Macao Greater Bay Area* (Zhaopin, 2019). According to the big data analysis in the report, all nine Guangdong cities in the GBA, in addition to Jiangmen, are in a state of net talent inflow. The top four talent inflow industries are real estate construction, Internet services, manufacturing and the automobile industry, most of which belong to the secondary sector as defined in this study. This further implies that the

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science and engineering university enrolments in Guangdong Province cannot satisfy the development of its secondary industry upgrading, at least in terms of quantity.

*4.2.2 Hong Kong.* A strong positive correlation between secondary industries and science and engineering enrollments was recognized. Surprisingly, the percentage of compositions of science and engineering students were much higher than the secondary sector industry proportions despite their simultaneous decline. The percentage of compositions of secondary industry GDP decreased from 19.49% in 1993 to 7.7% in 2016, while the proportion of science and engineering enrollments dropped from 45.09% to 36.01%. It seems that universities in Hong Kong still educate a large number of science and engineering talents although its secondary industries have shrunk notably in the last two decades. One possible explanation might be that college graduates with science or engineering backgrounds find it easier to enter other service industries or are preferred by employers ([Borah et al., 2019](#)). Another reason for this situation lies in the fact that the talents of Hong Kong and Macao have a significant trend of flowing to Beijing and Shanghai, accounting for 14% and 11% of their total outflows and surpassing mainland cities in the GBA ([Zhaopin, 2019](#)).

In spite of a strong positive correlation between the tertiary sector and its corresponding disciplines as a whole, the situation varied a lot amongst different disciplines. Humanities and education both showed a strong positive correlation. Medicine exhibited a very strong positive correlation. Unexpectedly, economics and business management studies indicated a very strong negative correlation (see [Table 1](#)). It might be reasonable to infer that medicine, humanities and education programs have produced sufficient graduates to satisfy industry demands, while the number of local talents with economics and business management backgrounds are not sufficient to support the development of the financial industry. As an international financial center, Hong Kong has a strong absorption capacity for high-end talents. Beijing and Shanghai are the main sources of its talent inflows, accounting for 26.66% and 12.43%, respectively ([Zhaopin, 2019](#)). Possibly, part of this inflow has filled in the gap caused by insufficient local graduates.

*4.2.3 Macao.* Although tertiary industries constitute the major sector, making up over 90% of the GDP, the data analysis confirmed no significant correlations between university enrollments and tertiary sector industries. To some extent, this suggests that changes in enrollments in Macao's tertiary institutions have not closely responded to its local industry demands. As for the moderate positive correlation between secondary industries and their corresponding disciplines, it is not large enough to draw any conclusions considering the very small numbers of science and engineering graduates in Macao every year. Given that the average percentage of composition of GDP for the gaming industry has reached over 50%, it seems that other industries have been developed based on this core industry. In light of this unique phenomenon, the researchers further investigated the disciplines and discovered that a specialized academic program called "Personal Services" has attracted a large number of enrolments, accounting for over 20%. Business & Administration and Personal Services, respectively, have been the first and the second most popular academic programs in Macao's universities. Further exploration of this unique discipline is needed in future studies to understand its relationship with the gaming industry.

### *4.3 Limitations*

In general, this study had two limitations in terms of its data sources and correlation analysis design. First, the enrollment data of different disciplines in Guangdong and Macao before 2004 and 2003, respectively, is hard to obtain. As for Hong Kong, the enrollment data used in this study only covered UGC-funded universities. Additionally, this study applied the p-statistic where  $p$  is less than 0.05 to indicate the significance of the results. Although  $p < 0.05$  can suggest that the observed results are not caused by random chance ([Gall et al., 2005](#)), it is

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better to adjust the alpha from 0.05 to 0.01 when several null hypotheses are to be examined ([Armstrong, 2014](#)).

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## 5. Discussions and conclusion

### 5.1 Complementarity among regions

This study was conducted based on the concepts of complementarity and regional integration development of higher education in the GBA. From the perspective of economics, complementarity refers to a situation in which cooperation between a number of entities can improve their own capacities, while their internal inputs can also improve the marginal benefits of cooperation ([Yi, 1996](#)). With regard to global engagement, financial leverage, system diversification and university autonomy, the characteristics of the higher education systems in Hong Kong and Macao can facilitate higher education transformation in Guangdong. Conversely, we can find some evidence of how the characteristics of universities in Guangdong can feedback into the other two regions.

The nine Guangdong cities of the GBA have a solid manufacturing base and a relatively complete industrial chain. Shenzhen is competitive in the fields of finance, technological innovation, emerging industries and ecological environment. Guangzhou is well-known as an international industrial service center and a global logistics hub ([Xie et al., 2019](#)). At the same time, the core cities in the Pearl River Delta and the cities aside can achieve coordinated development. For example, Zhuhai's high-end manufacturing industry can complement Zhongshan's professional market base. Guangzhou's advanced manufacturing and high-end services can complement Foshan's industrial base.

According to statistics on the three regions, the proportions of tertiary industries within their economies continue to increase; the tertiary sector remains the industrial pillar of the entire GBA. The most recent statistics for Hong Kong and Macao show that the tertiary industry accounts for more than 90% of the total output value. Hong Kong's manufacturing industry accounted for only 7.7% in 2016. As the world's third-largest financial center, a global logistics center and the "super contact" of China, its pillar industries are modern production services such as warehousing, logistics and professional services; and its advanced nature can drive the development of both manufacturing and service industries in the Pearl River Delta. Macao has close trade links with Portuguese-speaking countries and can serve as a link between the GBA and Portuguese-speaking countries.

### 5.2 Industrial structure deviation

This study has recognized that the number of science and engineering talents graduating from the universities in Hong Kong exceeds the demands of Hong Kong's secondary industries, but the cities in Guangdong that need such talents are not the first choice of most Hong Kong graduates ([Zhaopin, 2019](#)). Moreover, talents with economics and business management backgrounds are greatly needed by Hong Kong, but there are more Hong Kong graduates in medicine than are needed. These conclusions were drawn from the correlation analysis, but further research is needed to justify these claims. The statistics for Hong Kong have superficially reflected its increasingly solid industrial structure and development model. Hong Kong is actually facing a series of problems, including weak economic growth, a small proportion of the real economy, excessive dependence on the service industry, insufficient development flexibility and antirisk capabilities, and social unrest caused by the solidification of social class ([Liang, 2018](#)). The development of the GBA is a golden chance for Hong Kong to restimulate the vigor of its social and economic development.

On the other hand, Shenzhen's short supply of medical resources was emphasized by Chen Rugui, the Mayor of Shenzhen, in the *Government Work Report* issued in March 2019 [[2](#)].

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Other than that, the most remarkable deviation in the situation of Guangdong is the imbalance between the secondary industrial sector and university enrolments in science and engineering (see [Table 1](#)). That is to say, the science and engineering talents cultivated by universities in Guangdong cannot satisfy the needs of the secondary industries in Guangdong. In addition to strengthening the disciplines of science and engineering in Guangdong, the key is to build up a talent ecosystem among cities of the GBA that is beneficial for talent flow, talent sharing and talent cultivation in a complementary manner.

### *5.3 Creating a talent ecosystem*

In conclusion, the calculated industrial structure deviation and the analyzed complementarity of the 9 + 2 cities and the three regions of the GBA in terms of industrial and university discipline structure call for a talent ecosystem that allows cross-regional mobility of different types of human resources, in particular, research-oriented, scientific and technological talents. However, the institutional environment of the GBA for talent flow is unique and more complicated than that in other international bay areas, as the GBA steps across three customs zones involving different administrative and legal systems ([Jie et al., 2019](#)). This is essential when considering talent cooperation and circulation within the Area ([Zu and Mei, 2018](#)).

Since 2012, Nansha in Guangzhou, Qianhai in Shenzhen and Hengqin in Zhuhai have been developed as pilot free trade zones to explore feasible mechanisms for talent circulation within the GBA. In May 2016, 20 policy measures were issued covering areas such as institutional mechanism innovation, entrepreneurship support and comprehensive services to facilitate talent circulation, including visa and residence, entrepreneurship incentives, intellectual property protection, housing security, children's schooling, transportation convenience, etc. ([Jie et al., 2019](#)).

Talent circulation is merely the first step to achieving talent sharing and the establishment of a talent ecosystem that relies more on higher education cooperation based on the concept of regional integration development. At the macrolevel, the decision-makers should consider the GBA as an entire higher education ecosystem when designing university disciplines and interdisciplinary programs; the three regions and the 9 + 2 cities should be interactive and complementary in terms of their higher education resources and outputs. At the microlevel, universities in the GBA can design specific university disciplines in response to the needs of the local industry. We can take the intelligent manufacturing industry as an example ([Fei et al., 2019](#)). In the GBA, there is a structural shortage of talents in this field, which has impeded technology innovation. In response to the needs of the industry, the university discipline of intelligent manufacturing and a talent training system can be designed and constructed on the basis of the existing universities in the GBA. The university programs can take an order model and engage with the industries; in this case, the graduates would be tailor-made professionals for this industrial sector.

Thanks to geographical advantages, higher education cooperation between Guangdong, Hong Kong and Macao has had a remarkable history ([Xie et al., 2019](#)). However, the GBA still has a long way to go to achieve substantial cooperation and integration. The most persuasive reason for working toward this goal is that the overall university discipline layout of the GBA, based on loose geographical connections, currently impedes the progress of regional industrial transformation ([Lei, 2017](#)). The misallocation of university disciplines and barriers to talent flow and sharing across administrative constraints are vital problems that must be addressed in order to achieve regional higher education integration and further, sustainable economic development.

### *5.4 Policy implications and further research*

On July 5, 2019, the government of Guangdong issued the "*Implementation Opinions of Guangdong Province on the Outline Development Plan of the Guangdong-Hong Kong-Macao*

Greater Bay Area” (the “*Implementation Opinions*”). The “*Implementation Opinions*” outline a clear layout of the urban industrial structure. The picture of the correlations drawn by this study can provide a reference to promote complementary development according to the comparative advantages of the cities in the GBA.

Moreover, if a talent ecosystem is to be established, the most salient challenge is that there are no special laws and regulations commonly agreed upon and formulated by the three regions to ensure talent circulation within the Area. This can be partially attributed to the different legal systems. Therefore, a macrolevel governance mechanism and cross-border coordination would be significant for building up a healthy talent ecosystem. This study can provide implications for macrolevel university discipline design and resource allocation and can help further explore breakthroughs in legal and administrative barriers.

As indicated by the limitations described in [Section 4](#) above, further research in the form of mixed-method case studies is suggested. In the era of the 4th Industrial Revolution and digital transformation, when every company in every industry has to become technology-centered, it is no longer possible just to procure one solution and deploy it. Each industry has to operate in a systemic manner like a digital organization. As a result of the revolutionary changes in the industry, the boundaries between university disciplines should become vaguer; new industries require talents with integrated capacity, which directly influences the university discipline layout.

New industries in the GBA can be selected as cases for future research, for example, artificial intelligence, robotics, biotechnology, large aerospace industries and 5G. First, interdisciplinary knowledge maps related to the selected industries could be constructed. Second, industrial data could be collected on patent outputs, the status quo of university-industry research cooperation, and the university discipline background and geographical origins of employees and their salary situations. Third, university data could be collected on the design and layout of the selected industry-related disciplines and majors in universities in the GBA, research and patent outputs, technology transfer, and student admissions and employment status. Finally, based on the collected data, case studies on the correlation between the university discipline structure and industrial layout could be done from an interdisciplinary perspective.

## Notes

1. The percentage of composition of primary sector GDP in Hong Kong & Macao is statistically negligible, so its relationship with the percentage of composition of university enrollment is not listed.
2. [http://www.sz.gov.cn/zfgb/2019/gb1091/201903/t20190313\\_16683064.htm](http://www.sz.gov.cn/zfgb/2019/gb1091/201903/t20190313_16683064.htm), *Government Work Report of Shenzhen*, March, 2019

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