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Innovative Cities and City Clusters in the Era of Digital Economy: A Talent Perspective

November 2019

• Research Group •

清华经管学院 Tsinghua SEM | CIDG Center for Internet Development and Governance 互联网发展与治理研究中心

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• Key Findings •

In this report, we analyzed the employment of digital talent, the representativeness of digital skills and the flow of digital talent across 26 cities in 11 worldwide city clusters. By comparing the industry distribution, education, seniority, skill characteristics of digital talents across multiple cities, we attempted to identify unique strength - of each city cluster and provided valuable insights around how each city can build upon its existing comparative advantages. We also studied the flow of talent within and between cities, as an indicator of the global transfer of knowledge as well as development of international connectivity and digital innovation.

1. While digital talent is strongly represented in both ICT and non-ICT industries, we observed that the proportion of digital talent in non-ICT industries was higher than that in ICT industries overall. This is a promising indication that digitization is expanding beyond ICT into other industries, including manufacturing, healthcare, finance, corporate services, consumer goods, education, and media and communications.

2. At the same time, we noticed that the proportion of digital talent across different industries also reflected the varying economic emphasis of the city that the industries were located in - for example, financial hubs like New York and London had higher proportions of digital talent in the finance industry, while commercial and innovative centers such as Guangzhou and Shenzhen showed greater concentration of digital talent in the consumer goods industry. This suggests that the digitization path is closely related to a region's existing strengths, since it is more efficient to build off existing infrastructure and ecosystems.

3. Looking at the representative digital skills, we saw that each city had its own unique set of representative digital skills and competitive advantages. Looking at the digital skills penetration ratio within each cluster, we also saw that cities within a cluster had distinctive traits - for example, in the Boston-Washington cluster, Washington was relatively stronger in cybersecurity while Boston was stronger in robotics.

4. We classified digital skills into tech skills and disruptive tech skills for further analysis. We observed that: 1) city clusters that have competitive advantage in both tech skills and disruptive tech skills include: Boston-Washington city cluster, SF Bay Area, UK-Ireland city cluster, Sydney Bay Area and Bangalore; 2) city clusters that have competitive advantage in disruptive tech skills include: Germany city cluster, Triple J (Jing-Jin-Ji) City Cluster, YRD city cluster and Singapore.

5. Boston-Washington city cluster is the most important source of digital talent in the world major city clusters. Besides, there is a greater tendency to migrate within one's cluster, or to clusters which are geographically nearer. We also found that the flow of digital talent showed different characteristics in within-region migration and between-region migration. For instance, Boston-Washington, UK-Ireland and Germany city clusters tend to have more within-region migration, while the clusters in China (Yangtze River Delta, Greater Bay Area and Triple J behave the opposite, exchanging more with digital talent from outside of the regions.

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01

Introduction

With the penetration of digital technology into various fields of economic and social development, the digital economy is playing an increasingly important role in urban growth. On the one hand, the rapid growth of the digital economy has benefited from the accelerated process of global urbanization, and urban areas, especially some metropolis, have become the most prosperous centers in terms of the development of the digital economy. On the other hand, the digital economy also promotes the development of urbanization across many areas, such as technological and commercial innovation, which has not only brought new ideas and solutions to address the increasingly prominent problems in cities of energy supply, environmental protection and population growth, but also injected vitality into innovation and development potential in more fields.

In recent years, the Smart City and Innovative City development concepts have been accepted and welcomed by increasing numbers of people. Many countries are trying to use digital technology to make cities smart, innovative, convenient, efficient and clean. Based on their advantages in the fields of science and technology, finance, trade and manufacturing, some cities have vigorously promoted the integrated innovation of digital technology and traditional fields to become the centers of regional and even global digital innovation. Some of these have formed numerous globally influential innovation clusters, such as SF Bay Area, Boston-Washington city cluster in the US, London metropolitan area in the UK, Ruhr industrial region in Germany (centered around Hamburg), the YRD city cluster in China, and so on. These cities and city clusters have played an important leading role in regional and global digital innovation and industrial digital transformation. One of the most important reasons is that these regions have attracted a large number of talents from all over the world, especially those talent needed for the development of the digital economy.

In our first research report, "Digital transformation of China's economy: Talent and Employment", we put forward the concept of "digital talent", which defines digital talent as "people with ICT professional skills and cross-sector talents whose abilities complement and interrelate with ICT skills". With the development of digital technology, ICT professional skills and complementary skills are also constantly developed. This research is based on the division of skills in the LinkedIn talent database and defines the digital talent as the ones having at least one digital skill (including ICT professional skills and ICT complementary skills) to depict the talent most needed for digital innovation and digital economic growth. This concept breaks the traditional impression that digital talent are technicians, and leads more people to pay attention to the importance of digital skills in their career development. It also makes enterprises and governments realize the important role of digital talent in the digital transformation of companies and the growth of digital economies. We have conducted in-depth research into China's digital talent pool and found that there is a significant imbalance in the regional and industry distributions of these talents. Regionally, digital talents are mainly concentrated in Beijing, Shanghai, Shenzhen and other megacities; as for industry distribution, digital talent are mainly concentrated in a small number of industries such as ICT, manufacturing, finance, consumer goods and so on. This phenomenon attracted our attention. With the digital divide brought about by network infrastructure being gradually bridged, talents and skills may be becoming new constraints to the development of digital inclusiveness. This research attempts to expand the vision to a global scope, and through the analysis and comparison of employment status, skill characteristics and migration of digital talent in 11 city clusters and 26 cities, we have garnered in-depth insights into how different regions and cities have established their development advantages in the digital economy based on their digital talent. We hope that this research can help governments, industries and individuals better understand the characteristics of digital talent in different regions and cities and the future development trends, and thereby provide a valuable reference and inspiration for policy formulation, enterprise development and an upgrade of personal skills. More importantly, we hope this research will promote digitized inclusive development across talent and skills. Up to now, some countries have integrated digital talent training and upgrading of digital skills into their national digital economy strategies, but this has been far from enough. The inclusive development of the digital economy requires more in-depth study, exchanges and cooperation among countries, regions, cities and people.

02

Regional Distribution of Digital Talent

For this research, 11 representative digital innovation city clusters are selected. These cities play an important role in regional and global digital innovation, and bring together innovative and digital talent from all over the world, including Boston-Washington City Cluster, SF Bay Area, Santiago, Germany City Cluster and UK-Ireland City Cluster, Sydney Bay Area, Bangalore, Singapore and Triple J (Jing-Jin-Ji) City Cluster, YRD City Cluster and GBA City Cluster in China. Based on data from LinkedIn, a well-known social platform for career professionals, we have screened nearly 15 million digital talent from these regions (as of December 2018). We deeply analyzed their regional and industry distribution, skill and migration characteristics, and compared and analyzed profile of talent in various regions, appeal of the regions to talents, and their impact on the local and global migration of digital talent and development of the digital economy. Table 2.1 shows 11 city clusters and 26 core cities included in the study, as well as the samples digital talents in each city cluster.

Table 2.1 Sample of Digital Talent in Major City Clusters around the World

City Clusters	Sample Size of Digital Talent
SF Bay Area (USA)	1.7M
Boston-Washington City Cluster (USA)	6M
Santiago (Chile)	79K
Germany City Cluster（Germany）	600K
UK-Ireland City Cluster （UK+IR）	1.5M
Sydney Bay Area (Australia)	600K
Bangalore (India)	1.4M
Singapore	590K
The Triple J (Jing-Jin-Ji) City Cluster (China)	400K
The YRD City Cluster (China)	600K
The GBA City Cluster (China)	600K

The main areas where digital talents are concentrated are Boston-Washington city cluster, SF Bay Area, the UK-Ireland city cluster and Bangalore in the Asia-Pacific Region. The Boston-Washington city cluster on the East Coast of the US has a large size and concentration of digital talent, amounting to more than 6 million and accounting for between 23.8% and 31.3% of the total talents. The number in SF Bay Area on the West Coast of the US is more than 1.7 million, accounting for 32.6% of the total talents. The number of digital talent in the UK-Ireland city cluster is more than 1.5 million, accounting for 21.9% to 31.3% of the total talents. In the Asia-Pacific Region, digital talent in Bangalore are relatively concentrated, with a scale of more than 1.4 million, accounting for 36.6% of the total talents. In addition, Germany city cluster have more than 600,000 digital talent, accounting for 28.3% to 34.3% of the total talents. In recent years, the scale of the digital talent pool in the Triple J, the YRD and the GBA city cluster has grown rapidly, but the proportion of the total talents is still relatively low at below 20%.

03

Industrial Distribution of Digital Talent

Firstly, we analyzed the proportion of digital talent in ICT and non-ICT industries in different cities, as shown in Figure 3.1. The top 10 cities with the highest proportion of digital talent in ICT industries are Bangalore, Hangzhou, Beijing, Nanjing, San Francisco, Shenzhen, Guangzhou, Dublin, Shanghai and Munich, accounting for 32.1% to 63.2%. The top 10 cities with the highest proportion of digital talent in non-ICT industries are Philadelphia, New York, Birmingham, Manchester, London, Hong Kong, Baltimore, Santiago (Chile), Sydney Bay Area and Boston, accounting for 76.9% to 84.6%.

The proportion of digital talent in ICT industries and non-ICT industries can to a certain extent reflect the emphasis of different regions and cities on the development of the digital economy. As a whole, the proportion of digital talent in non-ICT industries is higher than that in ICT industries. In the cities we analyzed, the proportion of digital talent in ICT industries in Bangalore, Hangzhou and Beijing exceeded that in non-ICT industries. Correspondingly, Philadelphia, New York, Birmingham, Manchester, London and Hong Kong had the highest proportion of digital talent in non-ICT industries, accounting for above 80% of their respective totals.

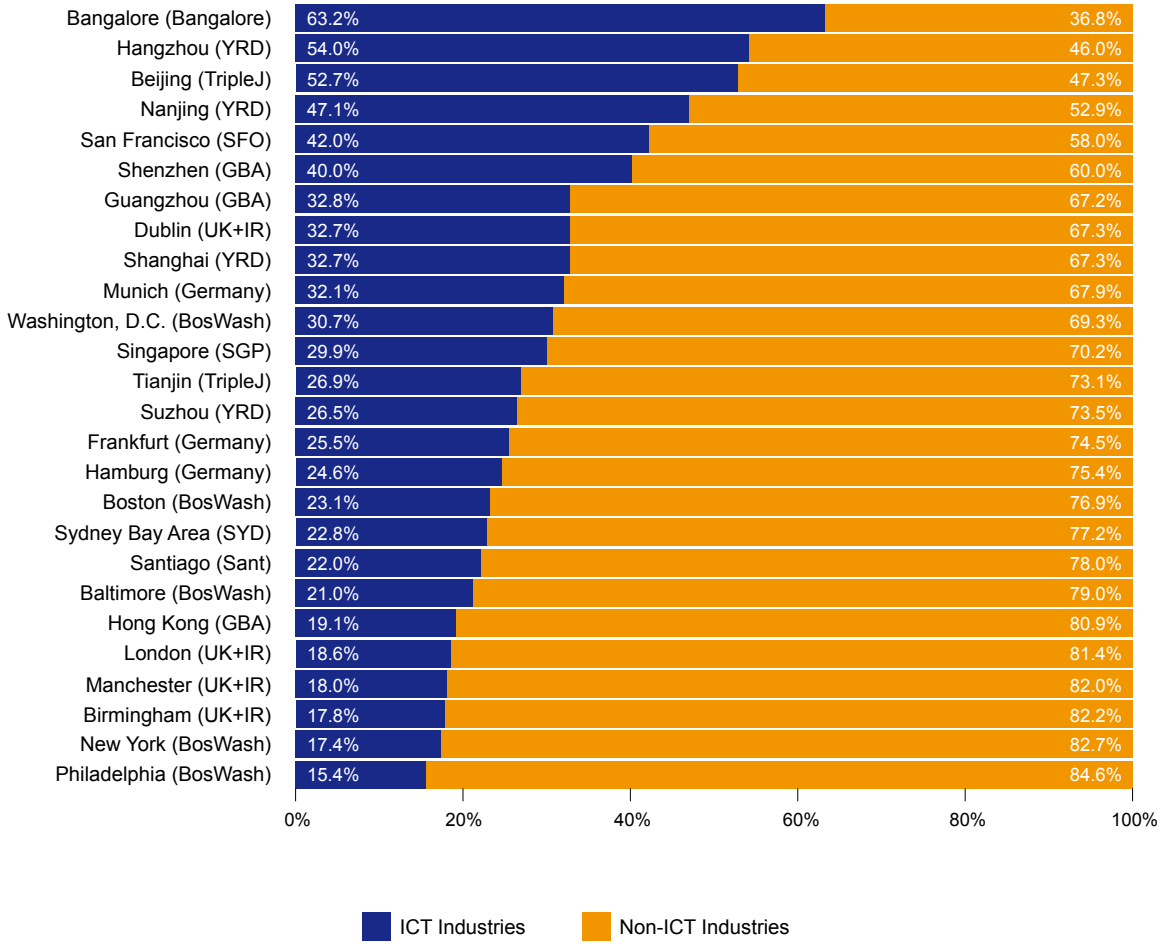

Figure 3.1 Industry Distribution of Digital Talent in City Clusters Around the World

We further analyzed the distribution of digital talent in non-ICT industries and Table 3.2 lists the three sectors with the highest proportions in non-ICT industries across different cities.

Table 3.2 Top Three Non-ICT Industries with the Highest Proportion of Digital Talent

City Cluster	City	Three Major Industries with the Highest Proportion of Digital Talent in Non-ICT Industries		
Boston-Washington City Cluster	Philadelphia	Healthcare	Finance	Education
	New York	Finance	Media & Communications	Consumer Goods
	Baltimore	Manufacturing	Education	Healthcare
	Boston	Healthcare	Education	Finance
	Washington, D.C.	Corporate Services	Education	Manufacturing
SF City Cluster		Healthcare	Consumer Goods	Education
Chile	Santiago	Manufacturing	Education	Corporate Services
Germany City Cluster	Hamburg	Manufacturing	Media & Communications	Corporate Services
	Frankfurt	Manufacturing	Finance	Healthcare
	Munich	Manufacturing	Corporate Services	Finance
UK-Ireland City Cluster	Birmingham	Manufacturing	Corporate Services	Education
	Manchester	Corporate Services	Education	Media & Communications
	London	Finance	Media & Communications	Corporate Services
	Dublin	Finance	Corporate Services	Healthcare
Bangalore		Manufacturing	Corporate Services	Finance
Singapore		Finance	Manufacturing	Corporate Services
Sydney Bay Area		Finance	Corporate Services	Education
Triple J (Jing-Jin-Ji) City Cluster	Beijing	Finance	Manufacturing	Corporate Services
	Tianjin	Manufacturing	Consumer Goods	Finance
The YRD City Cluster	Shanghai	Manufacturing	Finance	Corporate Services
	Nanjing	Manufacturing	Education	Consumer Goods
	Hangzhou	Manufacturing	Consumer Goods	Finance
	Suzhou	Manufacturing	Consumer Goods	Healthcare
The GBA City Cluster	Hong Kong	Finance	Consumer Goods	Corporate Services
	Guangzhou	Manufacturing	Consumer Goods	Corporate Services
	Shenzhen	Manufacturing	Consumer Goods	Finance

Among the non-ICT industries, those with the highest proportion of digital talent across the cities are manufacturing, healthcare, finance, corporate services, consumer goods, education, and social media. In the manufacturing industry, the three metropolitan areas with higher proportion of digital talent are the Germany city cluster including Munich, Hamburg and Frankfurt, and the YRD city cluster including Shanghai, Hangzhou, Nanjing and Suzhou. In the finance industry, areas with high proportion of digital talent included New York, London, Dublin, Singapore, Sydney Bay Area and Shanghai. In the healthcare industry, cities with high proportion of digital talent included Boston, Philadelphia and San Francisco. In the consumer goods industry, cities with high proportion of digital talent included Hangzhou, Hong Kong, Shenzhen and Guangzhou.

Boston-Washington City Cluster

Washington, D.C. has a large number of digital talents in corporate services, education and

manufacturing industries, accounting for more than 10.4%. Boston has a higher proportion of digital talents in the healthcare, education and finance industries, accounting for 15.7%, 12.6% and 9.9%, respectively. New York has a higher proportion of digital talents in the finance, social media, and healthcare industries, accounting for 14.6%, 10.3% and 9.7%, respectively. Baltimore has a higher proportion of digital talents in the manufacturing, education, and healthcare industries, accounting for 12.8%, 12.6% and 11.0%, respectively. Philadelphia has a large number of digital talents in the healthcare, finance and education industries, accounting for 16.2%, 12.3% and 10.2%, respectively.

SF Bay Area

SF Bay Area has a large number of digital talents in the healthcare, consumer goods and education industries, accounting for 8.9%, 7.7% and 7.6%, respectively.

Santiago (Chile)

Santiago's digital talents are concentrated in manufacturing, education and corporate services, accounting for 9.9%, 9.9% and 9.2%, respectively.

Germany City Cluster

Munich has a large number of digital talents in manufacturing, corporate services and finance, accounting for 21.2%, 8.3% and 5.7%, respectively. Hamburg has a large number of digital talents in manufacturing, social media, and corporate services, accounting for 17.1%, 11.9% and 8.4%, respectively. Frankfurt has a large number of digital talents in manufacturing, finance and healthcare sectors, accounting for 19.4%, 10.4% and 8.7%, respectively.

UK-Ireland City Cluster

London has a large number of digital talents in finance, social media, and corporate services, accounting for 16.8%, 12.3% and 11.3%, respectively. Manchester has a large number of digital talents in corporate services, education, and social media, accounting for 10.9%, 10.7% and 8.3%, respectively. Birmingham has a large number of digital talents in manufacturing, corporate services and education sectors, accounting for 15.8%, 11.7% and 9.7%, respectively. Dublin has a large number of digital talents in finance, corporate services and healthcare, accounting for 12.2%, 9.1% and 7.5%, respectively.

Sydney Bay Area (Australia)

The Sydney Bay Area has a large number of digital talents in finance, corporate services and education, accounting for 13.3%, 9.1% and 7.7%, respectively.

Bangalore

Bangalore in India has a large number of digital talents in manufacturing, corporate services and finance, accounting for 8.1%, 5.6% and 5.1%, respectively.

Singapore

Singapore has a large number of digital talents in finance, manufacturing and corporate services, accounting for 14.2%, 11.1% and 7.2%.

The Triple J (Jing-Jin-Ji) City Cluster

Beijing also has a large number of digital talents in finance, manufacturing and corporate services, accounting for 7.7%, 7.5% and 5.6%, respectively. Tianjin has a large number of digital talents in manufacturing, consumer goods and finance industries, accounting for 16.2%, 7.4% and 6.7%, respectively.

The YRD City Cluster

Shanghai has more digital talents in manufacturing, finance and corporate services, accounting for 18.4%, 8.3% and 7.6%, respectively; Nanjing has more digital talents in its manufacturing, education and consumer goods industries, accounting for 15.0%, 6.1% and 5.3%, respectively; Hangzhou has more digital talents in manufacturing, consumer goods and finance industries, accounting for 11.3%, 5.5% and 4.9%, respectively; Suzhou has more digital talents in its manufacturing, consumer goods and healthcare sectors, accounting for 37.7%, 7.3% and 5.0%, respectively.

The GBA City Cluster

Hong Kong has more digital talents in its finance, consumer goods and corporate services sectors, accounting for 22.5%, 11.7% and 7.1%, respectively; Guangzhou has more digital talents in manufacturing, consumer goods and corporate services industries, accounting for 13.0%, 12.5% and 6.2%, respectively; Shenzhen has more digital talents in its manufacturing, consumer goods and finance sectors, accounting for 18.0%, 13.5% and 5.9%, respectively.

• Chapter Summary •

Overall, the proportion of digital talent in non-ICT industries is higher than that in ICT industries.

The proportion of digital talent in ICT industries in Bangalore, Hangzhou and Beijing is higher than that in non-ICT industries.

Philadelphia, New York, Birmingham, Manchester, London and Hong Kong have the highest proportion of digital talent in non-ICT industries, all exceeding 80%.

Among non-ICT industries, those with the highest proportion of digital talent are manufacturing, healthcare, finance, corporate services, consumer goods, education, and social media.

In the manufacturing industry, Munich, Hamburg and Frankfurt in Germany, and Shanghai, Hangzhou, Nanjing and Suzhou in China have higher proportion of digital talent;

In the finance industry, New York, London, Dublin, Singapore, Sydney Bay Area, and Shanghai have higher proportions of digital talent;

In the healthcare industry, Boston, Philadelphia and San Francisco have higher proportion of digital talent.

04

Education Background and Seniority of Digital Talent

4.1 Education Background

We analyzed the education backgrounds of digital talent in the core cities of different city clusters (Figure 4.1). The top 10 cities with the highest proportion of digital talent with postgraduate education and above in descending order of proportion are Santiago (Chile), Frankfurt, Munich, Hamburg, Dublin, Beijing, London, Shanghai, Hong Kong, and San Francisco, of which the proportion of doctoral-degree digital talent in Hamburg, Munich and Frankfurt are the highest, reaching more than 6%, with that in Frankfurt as high as 9.1%. Boston, San Francisco, Baltimore, Washington, D.C. in the US, and Manchester and Birmingham in the UK also have a high proportion of digital talent with doctoral degrees.

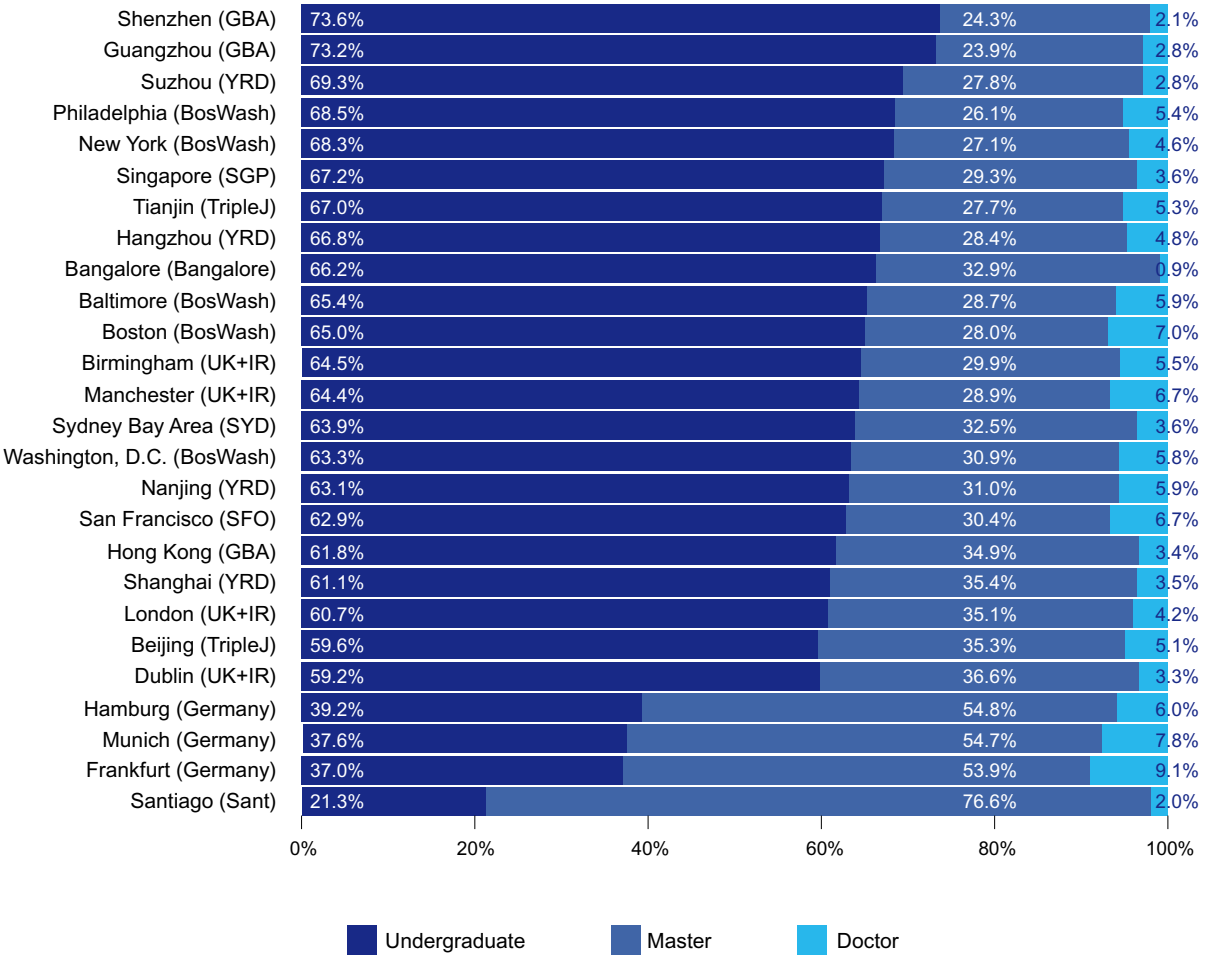

Figure 4.1 Educational Distribution of Digital Talent in Core Cities

Among the core cities in the Asia-Pacific Region, the Sydney Bay Area, Bangalore and Singapore have the highest proportion of digital talent with master's degrees and above, at 36.1%, 33.8% and 32.8%, respectively. However, the proportion of doctoral-degree digital talents in Bangalore is much lower than that in the other two cities, and the lowest among the 26 cities studied (0.9%). Among the three big cities in China, the education background of digital talent varied greatly. Except for Beijing and Shanghai, the proportion of digital talent with master's degrees and above in other cities is relatively low. Among the 26 cities studied, Shenzhen, Guangzhou and Suzhou have the lowest proportion of digital talents with master's degree or above.

4.2 Seniority

We further analyzed the seniority held by digital talent in the core cities of different city clusters. As shown in Figure 4.2, the top 10 cities with the highest proportion of digital talent in the positions of middle & senior and above in the core cities are Sydney, Hong Kong, London, Singapore, New York, San Francisco, Philadelphia, Washington, D.C., San Diego (Chile), and Birmingham, and proportion between 58.8% and 62.0%. The top cities with the highest proportions of digital talent in the position of director and above are New York, London, San Francisco, Hong Kong, Hamburg, Washington, D.C., Boston, Philadelphia, Baltimore and Munich, and the proportions range from 19.3% to 23.2%. Bangalore has the highest proportion of digital talent in senior professional positions among all cities, but the lowest proportion of those in positions of manager, director and above.

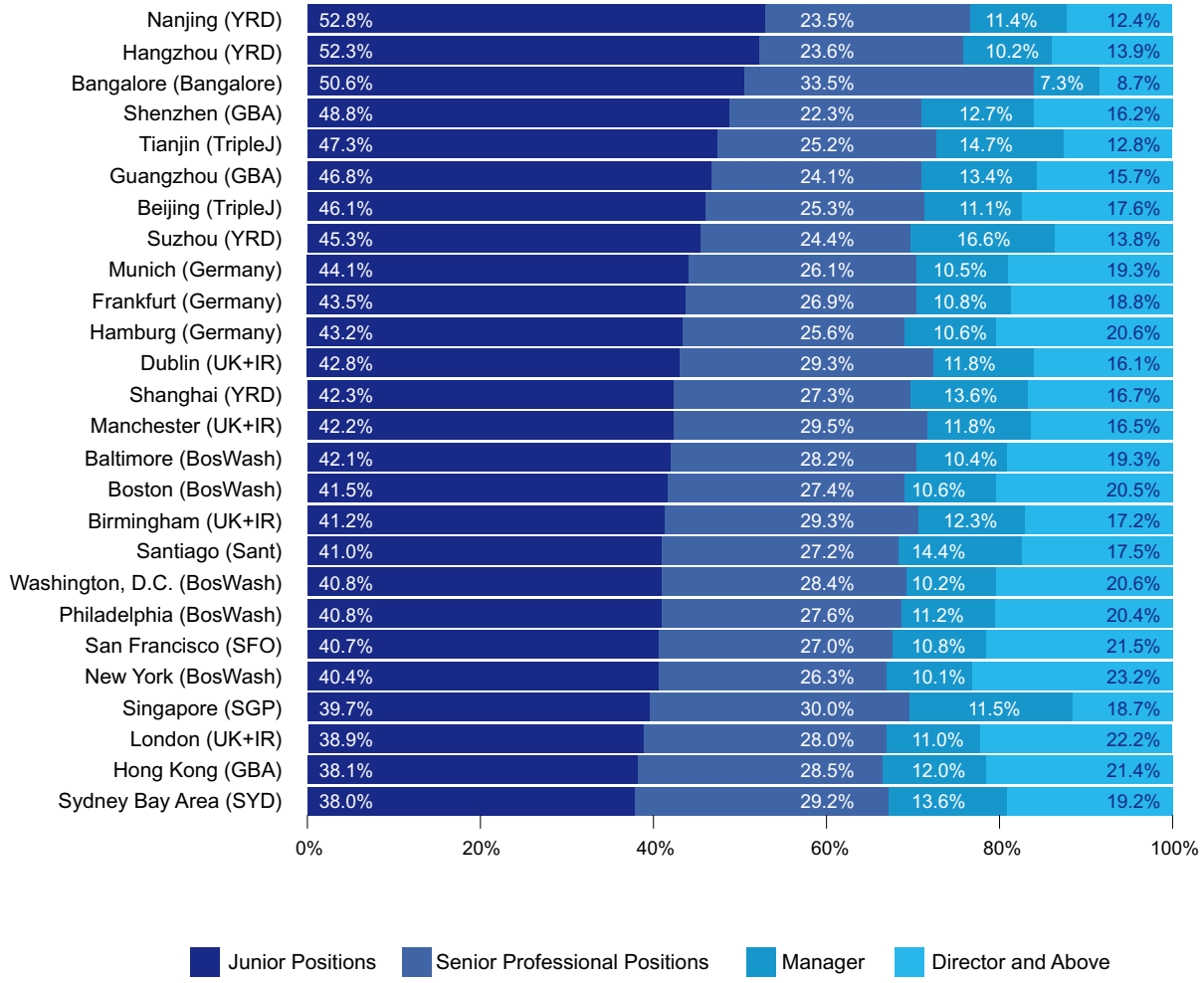

Figure 4.2 Distribution of Seniority Among digital talent in Core Cities

• Chapter Summary •

Digital talent has the highest percentage of undergraduate degrees, accounting for more than 60% in the majority of cities. The master's degree is the second, and the doctoral degree is the lowest.

The top 10 cities with the highest proportion of the digital talents with a Master's degree or above are Santiago (Chile), Frankfurt, Munich, Hamburg, Dublin, Beijing, London, Shanghai, Hong Kong and San Francisco.

The top 10 cities with the highest proportion of the digital talents with doctoral degrees are Frankfurt, Munich, Boston, San Francisco, Manchester, Hamburg, Baltimore, Nanjing, Washington, D.C. and Birmingham.

Digital talent are mainly concentrated in the junior positions, with more than 38% in all cities, followed by the senior professional positions, with more than 22% in each city, third in directors and above, and fourth in manager positions.

The top 10 cities with the highest number of digital talent serving as directors and above are New York, London, San Francisco, Hong Kong, Washington, D.C., Hamburg, Boston, Philadelphia, Munich, and Baltimore.

The top 10 cities with the highest number of senior and above positions are Sydney, Hong Kong, London, Singapore, New York, San Francisco, Philadelphia, Washington, D.C., San Diego (Chile), and Birmingham;

Three cities where digital talent serving in junior positions account for more than 50% are Nanjing, Hangzhou and Baltimore.

05

Specific Skills of Digital Talent

5.1 Representative Digital Skills of City Clusters

Different industries have different requirements for digital talents. The development of disruptive technologies is placing increasingly higher demands on the skills of digital talent (especially their digital skills). This research provides an in-depth analysis of the representative digital skills in different regions and city clusters so as to better demonstrate their unique characteristics in the digital transformation of industries.

Based on LinkedIn's Skills Genome method, this research analyzed the representativeness of digital skills across 26 cities in 11 city clusters (Due to the limitation of data, skills genome of some cities are not presented). First of all, we identified the talents reporting digital skills in each city and cluster. Secondly, we looked at the most common skills present in each occupation for each city and city cluster, and we computed the proportion of digital skills among all top 50 most frequent skills, and we called this "penetration rate". Finally, for each city and city cluster, we calculated the ratio of the average penetration rate, to that of the average across all 26 cities for the same set of occupations, and defined this ratio as a relative penetration rate. This relative penetration rate intuitively shows the representativeness of digital skills in a city, and at the same time, can be used to build comparisons across cities. For example, consider cities A and B: if the relative penetration of a given digital skill is higher in A than in B, it means that the average occupation in city A has a higher prevalence of such digital skill as compared to city B.

Based on the above analysis, we ranked the relative penetration rate of digital skills for each city and choose the top three as the city's representative digital skills. Meanwhile, we defined disruptive tech skills [1] as those that align with the World Bank's methodology and definitions. Compared with tech skills which enable workers to use new technologies, disruptive tech skills are the ones which workers harness in order to create new technologies and disruptive innovation. In terms of digital economic development for cities, both tech and disruptive tech skills are important since tech skills can provide the ability to leverage and embrace the digital world while disruptive tech skills can create new scenarios for the digital era. As shown in Figure 5.1, we list top three representative digital skills of 26 core cities in 11 city clusters, in which the blue color represents tech skills and the purple color represents disruptive tech skills. Based on the result, each city cluster has a unique focus on disruptive tech skills and tech skills. For tech skills, social media, game development, graphic design, etc. are key areas to develop while for disruptive tech skills, robotics, AI, aerospace engineering, genetic engineering, data science etc. are the major breakthrough areas. From the perspective of the city cluster, the representative skills of Boston-Washington city cluster, the SF Bay Area, UK-Ireland city cluster, Sydney Bay Area and Bangalore include both tech skills and disruptive tech skills; while for Germany city cluster, the YRD city cluster, Triple J (Jing-Jin-Ji) city cluster, GBA city cluster and Singapore, etc., the representative skills mainly include disruptive tech skills.

[1] The concepts of disruptive tech skills derives from World Bank's definition of disruptive technologies, detailed in "Disruptive Technologies and the World Bank Group" and "World Bank Group-LinkedIn Data Insights: Jobs, Skills and Migration Trends Methodology and Validation Results".

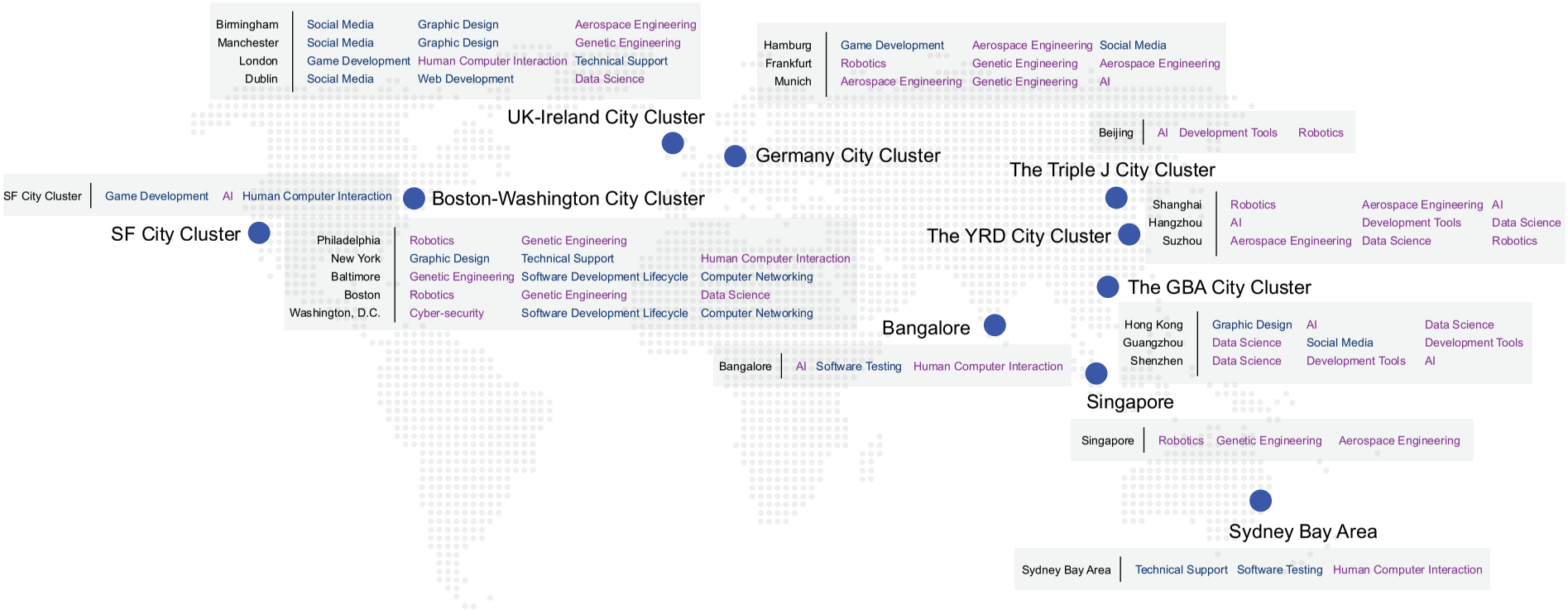

Figure 5.1 Representative Digital Skills of Core Cities in the World

5.2 Digital Skills Genome of City Clusters

Based on the analysis of representative digital skills in Section 5.1, we selected the top 10 tech skills and 8 disruptive tech skills prevalent among digital talents. Tech skills include: Computer Hardware, Computer Networking, Data Storage Technologies, Game Development, Graphic Design, Social Media, Software Development Lifecycle, Software Testing and Web Development; disruptive tech skills included: Aerospace Engineering, AI, Cyber-security, Data science, Development Tools, Genetic Engineering, Human Computer Interaction, and Robotics. According to the relative penetration rates of digital skills, we mapped the digital skills penetration rate of city clusters and analyzed the uniqueness and superiority of different cities in terms of their digital skills. If the relative penetration rate of a digital skill is greater than 1, it means that the average occupation in that city or city cluster has a higher representativeness of such skill as compared to the average level in the 26 cities. A higher relative penetration rate indicates that that skill is more prominent in the city.

5.2.1 The Boston-Washington City Cluster

The Boston-Washington city cluster is composed of five core cities: New York, Washington D.C., Boston, Baltimore and Philadelphia. The Boston-Washington city cluster has the highest prominence of talent with tech skills and disruptive tech skills, as shown in Figure 5.2. New York is the strongest overall in most of the skills showed. It has a rich talent pool of tech skills such as Graphic Design, Web development, and disruptive tech skills such as AI and human-computer interaction. The most prominent digital skill in Washington D.C. is Cyber-security. Baltimore is very similar to Washington D.C. in the skill structure of digital talents. Boston shows greater strength in robotics, human-computer interaction and genetic engineering. And Philadelphia is very similar to Boston in terms of skill structure.

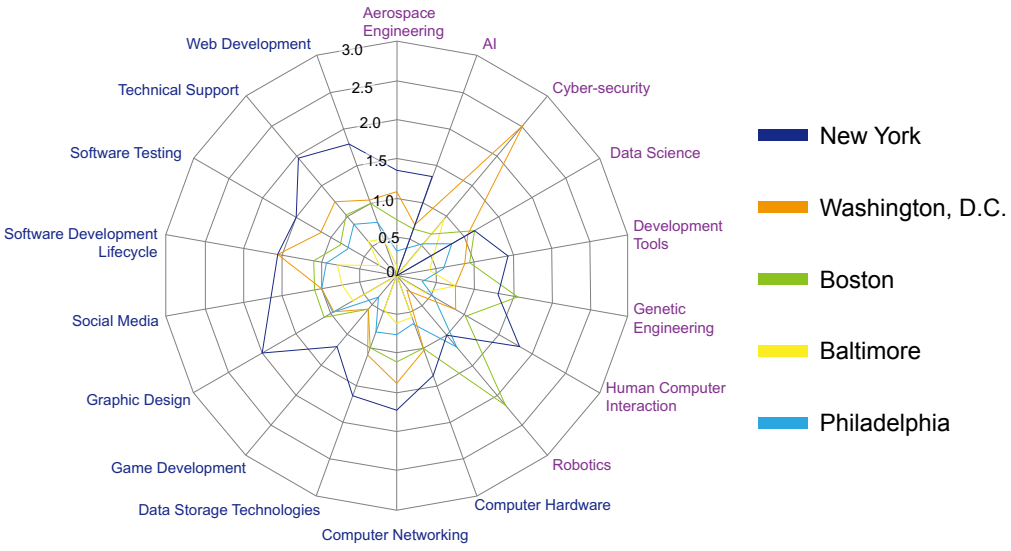

Figure 5.2 Digital Skills Genome of the Boston-Washington City Cluster

5.2.2 The SF Bay Area

The SF Bay Area has extremely high number of talent with most of the tech skills and disruptive tech skills, as shown in Figure 5.3. The SF Bay Area shows greater strength in tech skills such as game development. The most unique disruptive skills are human-computer interaction and AI, with the penetration rates being more than double that of the other skills.

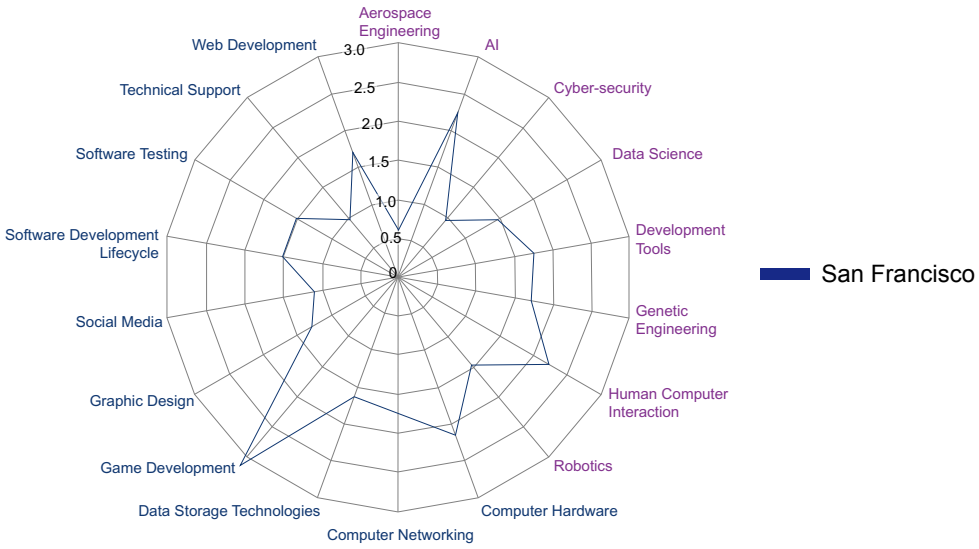

Figure 5.3 Digital Skills Genome of The SF Bay Area

5.2.3 The UK-Ireland City Cluster

The cities studied in the UK-Ireland city cluster are London, Manchester, Birmingham and Dublin. The digital skills genome of various cities is shown in Figure 5.4. As the capital center, London understandably is the strongest all-around. London's most prominent disruptive tech skills include human computer interaction and data science, and has a large digital talent pool with tech skills such as game development, graphic design and technical support. Manchester and Dublin are very similar in terms of the composition of their talents' digital skills, focusing on tech skills.

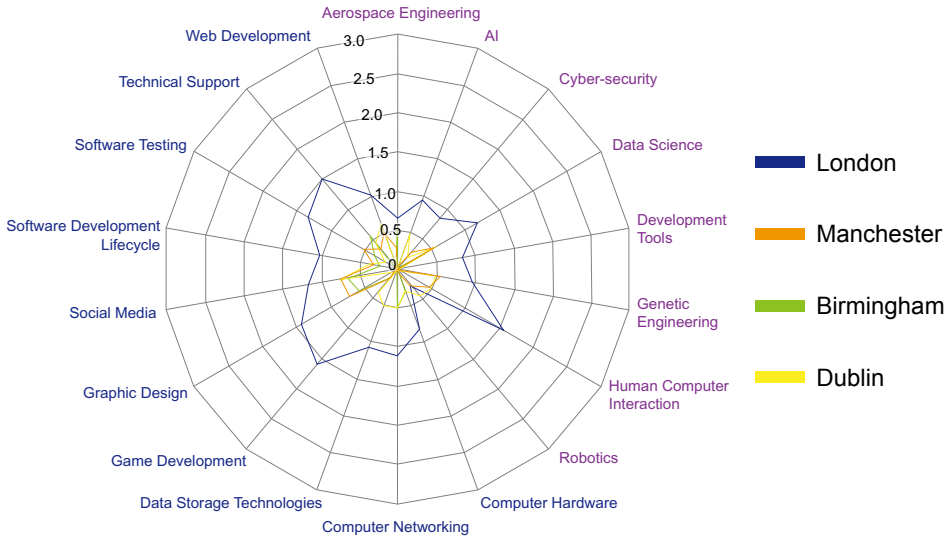

Figure 5.4 Digital Skills Genome of the UK-Ireland City Cluster

5.2.4 The Germany City Cluster

Germany City Cluster include three core cities, namely, Munich, Hamburg and Frankfurt, as shown in Figure 5.5. The most prominent disruptive tech skills in Munich and Hamburg is aerospace engineering, while in Frankfurt it is robotics. Besides the disruptive tech skills, the most prominent tech skill in Hamburg is game development. Munich and Frankfurt share a similar talent structure in terms of tech skills, but both fall behind the average level. In addition, Munich and Hamburg are generally leading in terms of genetic engineering in disruptive tech skills.

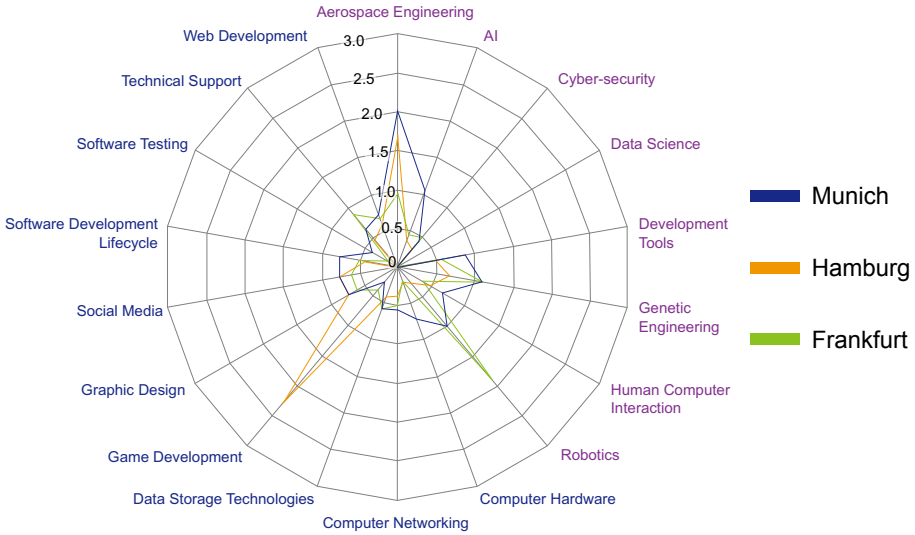

Figure 5.5 Digital Skills Genome of Germany City Cluster

5.2.5 The Triple J (Jing-Jin-Ji) City Cluster

The digital talents in the Triple J (Jing-Jin-Ji) city cluster is concentrated in Beijing. Compared with other cities, only Beijing showed uniqueness in its digital skills. Therefore, this section mainly analyzed the skills genome in Beijing, as shown in Figure 5.6. Beijing has more digital talent advantage in disruptive tech skills. The most unique digital skill in Beijing was AI, which is more than 1.5 times of the average level. Moreover, Beijing also owns advantages in Development Tools. When it comes to tech skills, Beijing has a relatively large reserve of digital talent with digital skills such as data storage technologies and game development.

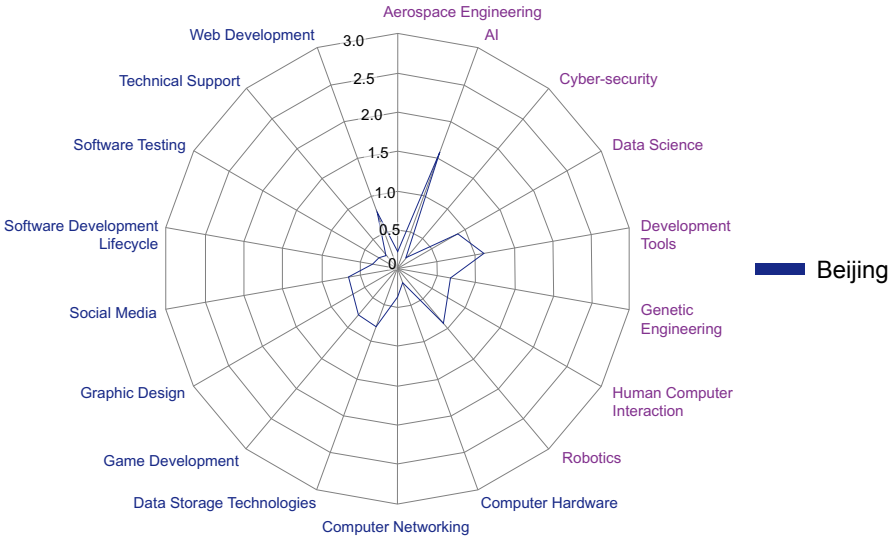

Figure 5.6 Digital Skills Genome of The Triple J (Jing-Jin-Ji) City Cluster

5.2.6 The YRD City Cluster

The YRD city cluster consists of four core cities including Shanghai, Hangzhou, Nanjing and Suzhou. Compared with tech skills, digital talents in YRD city cluster have more advantage in terms of disruptive tech skills, as shown in Figure 5.7. The most prominent disruptive tech skill in Shanghai is robotics, which doubles the average level; while in Hangzhou the most prominent skill is AI. The most prominent disruptive tech skill in Nanjing and Suzhou is robotics. But overall, except for Shanghai, the penetration rate of digital skills in other cities is relatively low.

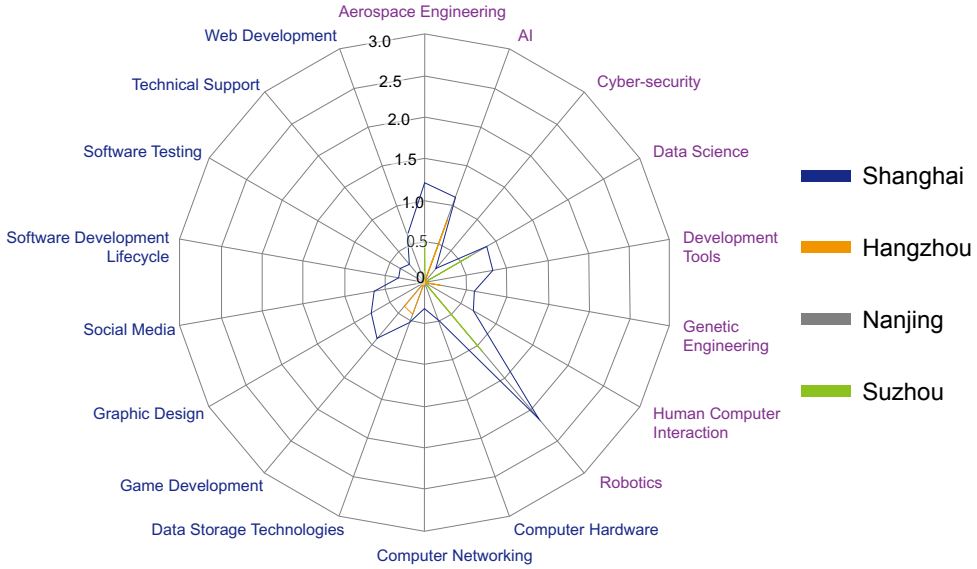

Figure 5.7 Digital Skills Genome of The YRD City Cluster

5.2.7 The GBA City Cluster

The GBA consists of three core cities, namely Shenzhen, Guangzhou and Hong Kong, whose digital skills genomes are shown in Figure 5.8. The most unique digital skill in Shenzhen and Guangzhou is data science; in Hong Kong it is Graphic Design; but both are below the average of 26 cities. In addition, Shenzhen and Hong Kong are similar in terms of the composition of their digital skills and Hong Kong has a stronger advantage on average.

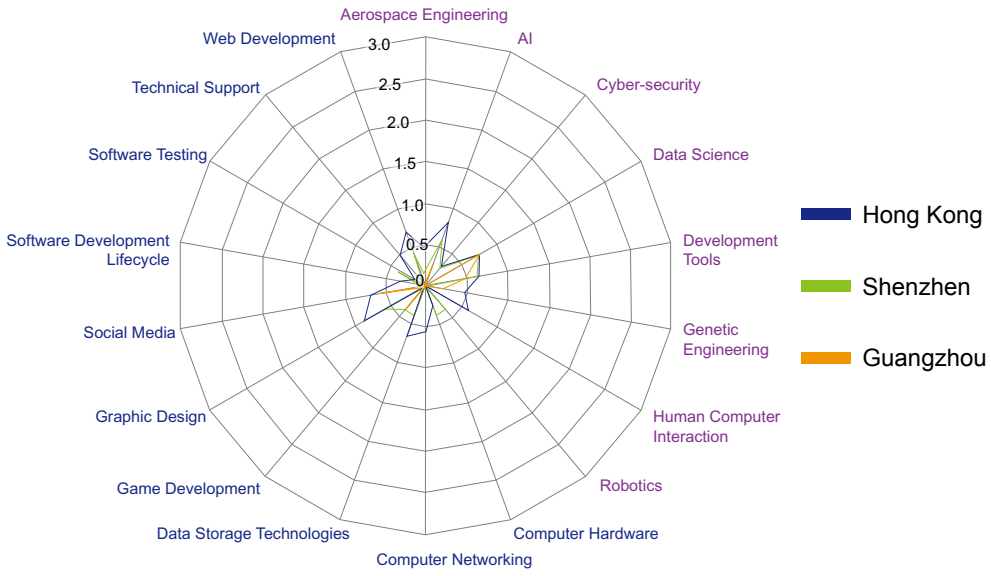

Figure 5.8 Digital Skills Penetration Ratio of China's GBA City Cluster

5.2.8 Other Core Cities -- Bangalore, Singapore, Sydney and Santiago

In addition to the above-mentioned city clusters, the research also analyzes four innovative cities, namely, Bangalore, Singapore, Sydney and Santiago. These four cities have different characteristics on tech skills and disruptive tech skills, as shown in Figure 5.9. The most unique digital skill in Bangalore are AI, aerospace engineering and development tools, all of which are more than twice the average with AI reaching 2.5 times the average. Bangalore also has more talent reserves in tech skills such as software testing and web development, especially in software testing and development tools are more than twice the average with software testing is 2.5 times the average. Singapore has a higher advantage on disruptive tech skills, with robotics being the most unique skill, and aerospace engineering and genetic engineering being relatively prominent compared to the rest skills. The most prominent skills in Sydney are technical support, software testing, game development and software development lifecycle, and robotics is also above the average. Santiago is more prominent in tech skills, such as web development, Graphic Design and data storage technology.

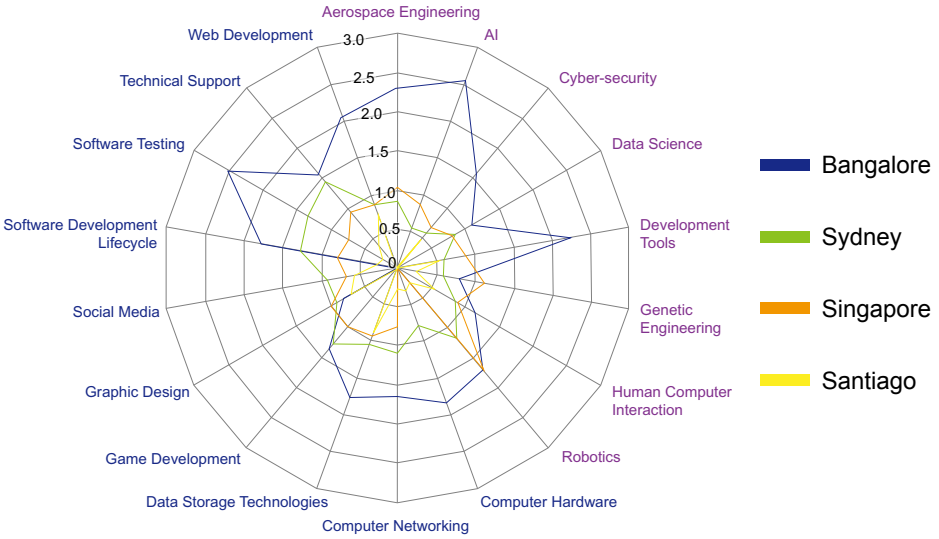

Figure 5.9 Digital Skills Genome of the Other Four Core Cities

• Chapter Summary •

Tech skills are the cornerstone of the development of digital economy in the city clusters. While Disruptive tech skills are an important driving force for the innovative development of city clusters. In the 11 city clusters of this research, city clusters with digital talent advantage in both tech skills and disruptive tech skills include: Boston-Washington city cluster, SF Bay Area, UK-Ireland city cluster, Sydney Bay Area and Bangalore.

New York has the highest proportion of digital talent in the Boston-Washington city cluster. It has a rich talent pool of tech skills such as animation, web development, and disruptive tech skills such as AI and human-computer interaction. The talent pool of disruptive tech skills such as Washington's network security and Boston's robotics is significantly ahead of the average of 26 cities.

The SF Bay Area's talent pool for most tech skills and disruptive tech skills is ahead of the average of 26 cities. The most unique tech skills is game development. The most unique disruptive tech skills are human-computer interaction and AI and exceed the average level twice in talent pool of these disruptive tech skills.

London is at the heart of the UK-Ireland city cluster. Its talent pool of tech skills such as game development, technical support, software testing, social media, and animation and disruptive tech skills such as human-computer interaction is ahead of the average.

The Sydney Bay Area leads the average in talent pool of tech skills such as technical support, software testing, game development, software development lifecycle and disruptive tech skills such as robotics.

Bangalore leads the average in talent pool of tech skills such as web development, software testing and its disruptive tech skills such as aerospace engineering, AI and development tools. Also, Bangalore exceeds the average level twice in talent pool of other skills such as web development, software testing, development tools, aerospace engineering, AI.

The city clusters with digital talent advantage in the disruptive tech skills include: Germany city cluster, Triple J (Jing-Jin-Ji) City Cluster, YRD city cluster and Singapore.

In the Germany city cluster, Munich's most prominent disruptive tech skill is aerospace engineering, as well as AI. Hamburg's most prominent disruptive tech skill is aerospace engineering. Frankfurt's most unique tech skill is robotics. Each of the three core cities has its own focus and diversified development.

Singapore's most unique digital skill is robotics, it also has other disruptive skills such as aerospace engineering and genetic engineering.

In the Triple J (Jing-Jin-Ji) City Cluster, Beijing's most unique tech skill is AI.

In the YRD city cluster, Shanghai plays a leading role. Its most unique tech skill is robotics, as well as aerospace engineering and AI. Suzhou's most unique tech skill is robotics.

06

Global Migration of Digital Talent

We analyzed the migration of digital talent among the city clusters from two perspectives: First, the attractions of different cities to digital talent are reflected in their inflow/outflow ratio; and second, reflecting the role of different city clusters in the pattern of global digital economic development through the migration of digital talent among the city clusters.

6.1 Digital Talent Attraction

We defined the cities' attractions to talent using the inflow/outflow ratio of digital talent, that is, the attractions of a city is equal to the ratio of the total inflow of digital talent to the total outflow. Figure 6.1 shows the attractions of 26 cities. The five cities with the highest attractions are Dublin, Santiago (Chile), Shanghai, Shenzhen and Bangalore. In the past four years, cities with net digital talent outflows included Beijing, Philadelphia, Guangzhou, Baltimore, Birmingham, Nanjing and Tianjin.

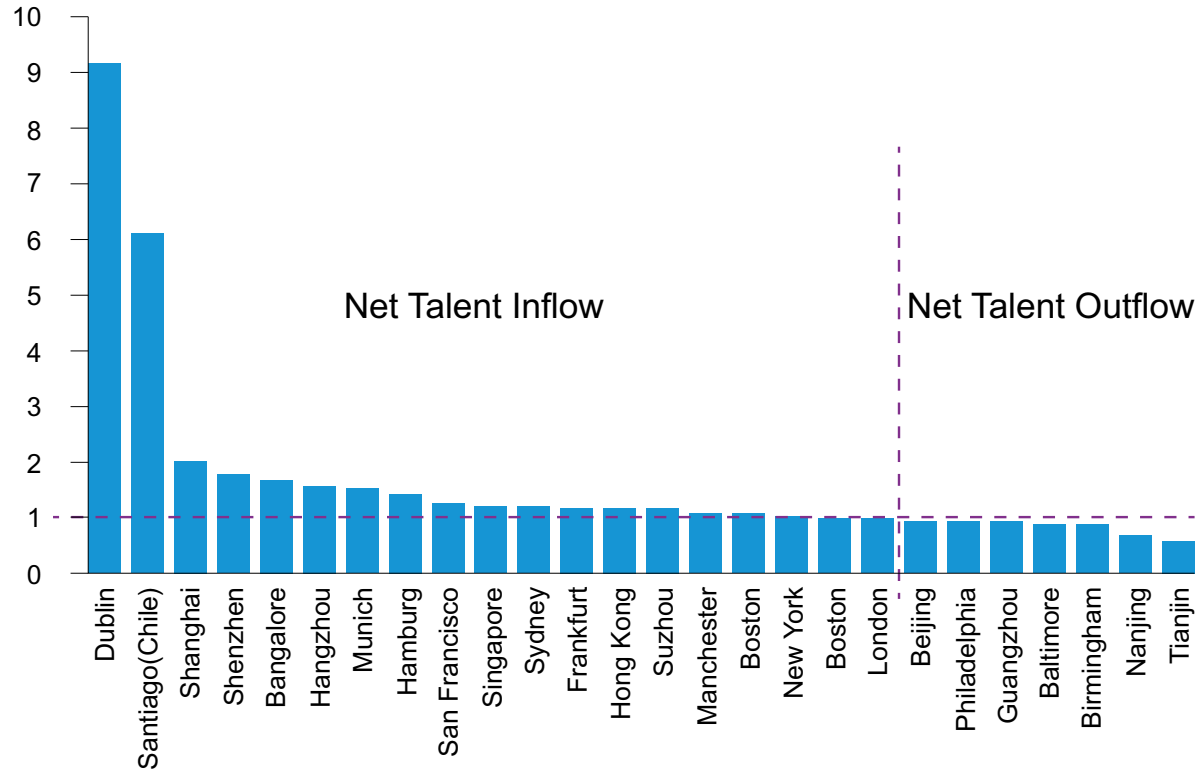

Figure 6.1 Attractions of Core Cities in Different City Clusters to digital talent

6.2 Migration of Digital Talent within City Clusters

Because of the small sample size of digital talent migration in Santiago, for this research we selected 10 other city clusters to analyze. We first examined the migration of digital talent in the urban and regional areas and outside of the city clusters which contained more than 1 city (this excludes clusters like the SF

Bay Area which only contains 1 city). The results in Figure 6.2 showed that compared with the other five city clusters, the Boston-Washington city cluster had the most frequent migration of digital talent between different cities within the region. The proportion of digital talent flow within the Boston-Washington city cluster, the UK-Ireland city Cluster and Germany city cluster is higher than the proportion migrating outside their regions, while the YRD city cluster, the GBA and the Triple J are precisely the opposite, especially the Triple J, where the migration rate within the region is only about 15%.

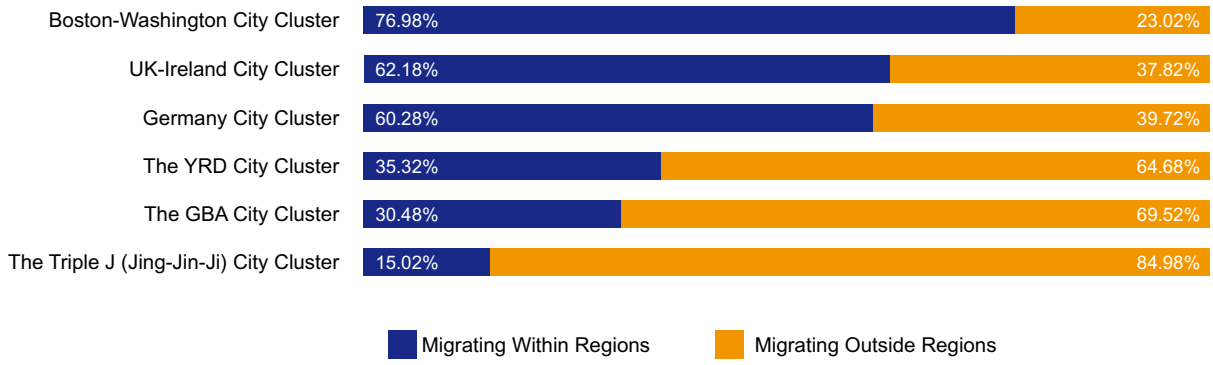

Figure 6.2 Proportion of Digital Talent in City Clusters Migrating within Their Regions Compared to Those Migrating Externally

6.3 Migration of Digital Talents among City Clusters

We further analyzed the migration of digital talent from the city clusters to destinations outside their regions. From the perspectives of both digital talent's sources and destinations, for each city cluster we calculated the ratio of digital talents moving from other city clusters to its total digital talent inflow as well as the ratio of digital talents migrating into other city cluster to its total digital talent outflow, in order to analyze the overall characteristics of digital talent migration among city clusters.

Overall, in the 10 city clusters studied, the most frequent migration of digital talent is between the Boston-Washington city cluster and the SF Bay Area, followed by migration between the YRD City Cluster, the GBA and the Triple J in China. From this perspective, these city clusters have more frequent domestic migration than with other international city clusters.

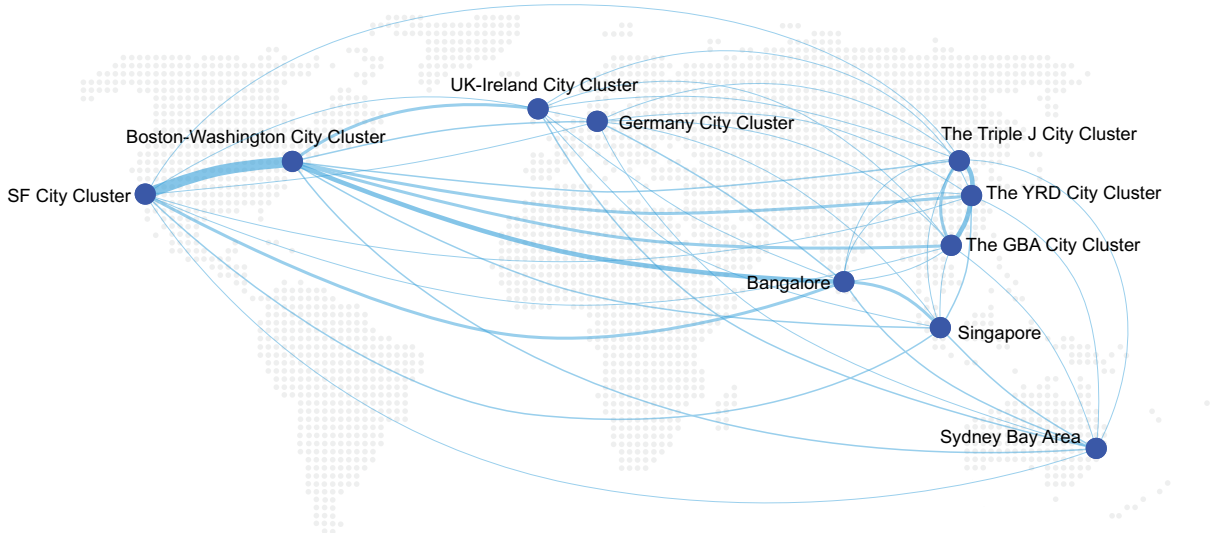

Figure 6.3 Network Map of Digital Talent Migration among City Clusters

Using data compiled on global digital talent migration we analyzed the distribution of digital talent inflow and outflow to examine the connectivity among the city clusters in terms of digital talents.

6.3.1 Digital Talent Sources

The top three sources of digital talent migrating to the Boston-Washington city cluster are the SF Bay Area, the YRD city cluster and the GBA city cluster. Among them, the SF Bay Area is the most important source, accounting for more than 70%. The YRD city cluster and the GBA city cluster, account for only 5% and 4.81% respectively. Based on this data, we see that the sources of digital talent migrating to the Boston-Washington city cluster are highly concentrated, and mainly in the United States.

Compared with the Boston-Washington city cluster, source of digital talent inflow for the SF Bay Area is more concentrated, coming mostly from the Boston-Washington city cluster, which accounts for 80% of the total. Bangalore, Singapore, the YRD city cluster and the GBA city cluster in the Asia Pacific region, are also important sources of digital talent for the SF Bay Area, although they account for less than 14% of the total.

Sources of digital talent migrating to the UK-Ireland city cluster are relatively scattered and balanced. The main sources of digital talent include the Boston-Washington city cluster, the Sydney Bay Area, the GBA city cluster and Singapore, accounting for 30%, 20%, 13% and 11% respectively of the total.

Sources of digital talent migrating to the Germany city cluster are also scattered and balanced. The main sources include the Boston-Washington city cluster, the UK-Ireland city cluster, the SF Bay Area and Singapore, accounting for about 28%, 14%, 13% and 11% respectively.

Digital talent migrating to the Triple J (Jing-Jin-Ji) City Cluster, the YRD city cluster and the GBA city cluster come mostly from mainland China, and migration of digital talent among the three major city clusters is relatively frequent. The largest sources of digital talent migrating to the Triple J (Jing-Jin-Ji) City Cluster include the YRD city cluster, the GBA city cluster and the Boston-Washington city cluster, accounting for 40%, 27% and 17% respectively. The largest sources of digital talent migrating to the YRD city cluster include the GBA city cluster, the Triple J (Jing-Jin-Ji) City Cluster and the Boston-Washington city cluster, accounting for 33%, 24% and 18% respectively. The largest sources of digital talent migrating to the GBA city cluster include the YRD city cluster, the Boston-Washington city cluster and the Triple J (Jing-Jin-Ji) City Cluster, accounting for 38%, 19% and 18% respectively. According to the data, alongside domestic digital talent flow sources, the Boston-Washington city cluster is the most important source of digital talent for the three major city clusters in China.

The Sydney Bay Area, Bangalore and Singapore receive relatively balanced and diversified sources of digital talent. The largest sources of digital talent migrating to the Sydney Bay Area include the Boston-Washington city cluster, Singapore, the UK-Ireland city cluster and the GBA city cluster, accounting for 21%, 20%, 17% and 12% respectively. The largest sources of digital talent migrating to Bangalore include the Boston-Washington city cluster, Singapore, the SF Bay Area and the Sydney Bay Area, accounting for 27%, 20%, 19% and 15% respectively. The largest sources of digital talent migrating to Singapore include the Sydney Bay Area, the Boston-Washington city cluster, Bangalore and the SF Bay Area, accounting for 22%, 19%, 17% and 15% respectively. It is clear that the Boston-Washington city cluster remains an important (possibly the most important) source of digital talent for these three major city clusters. Singapore is also an important source of digital talent for the Sydney Bay Area and Bangalore. On the whole, the Boston-Washington city cluster is the most important source of digital talent for major city clusters around the world, and plays a vital role in global digital talent migration and innovation. Geographical distance also has a significant impact on the migration of digital talent. For each city cluster, the adjacent city clusters are important sources of digital talents. Our research also found that the proportion of digital talent migrating from the three major Chinese city clusters to the Boston-Washington city cluster is significantly higher than from other city clusters, reflecting the active talent migration between the two areas.

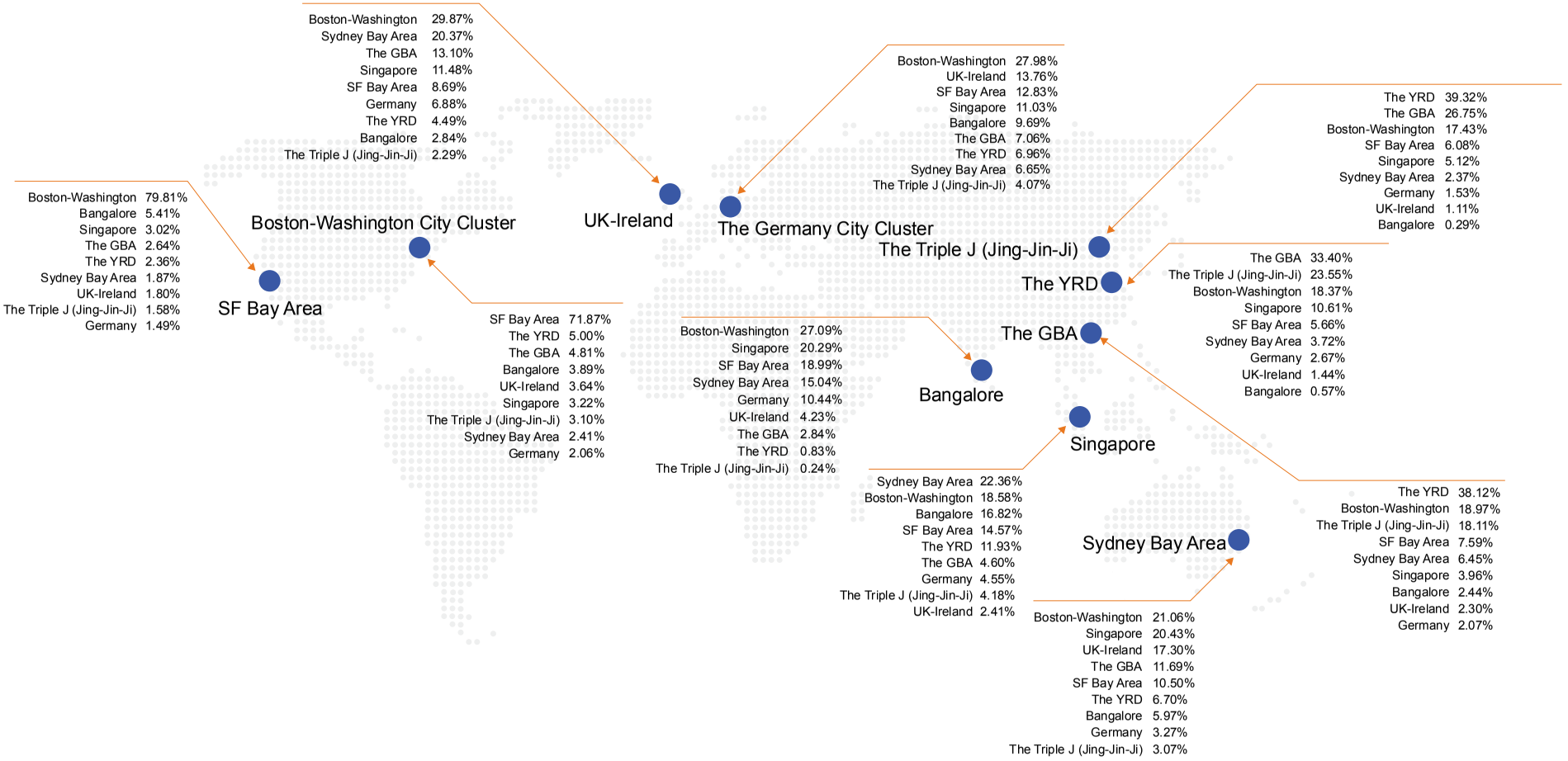

Figure 6.4 Distribution of Digital Talent Sources among City Clusters

6.3.2 Digital Talent Destinations

The Boston-Washington city cluster has a relatively concentrated outflow of digital talent. The top destination for digital talent is the SF Bay Area, which accounts for 61%. The next important destinations, Bangalore and the UK-Ireland city cluster, account for 9% and 7% respectively of the total outflow outside of the city clusters. In addition, a significant amount of digital talent migrates from the Boston-Washington city cluster to China's YRD and Triple J (Jing-Jin-Ji) City Clusters, which account for around 10% of the total. Compared with the distribution of sources, the destinations for digital talent from the Boston-Washington city cluster are more scattered, reflecting its widespread influence.

The destinations of digital talent from the SF Bay Area are more concentrated than from the Boston-Washington city cluster, with around 83% migrating to the Boston-Washington city cluster and 6% to Bangalore. The proportion of digital talent migrating to other city clusters is very low. Compared with the distribution of sources, the destinations of digital talent from the SF Bay Area are concentrated, reflecting the appeal of San Francisco.

Digital talent from the UK-Ireland city cluster migrates mainly to the Boston-Washington city cluster, the Sydney Bay Area, Bangalore, the SF Bay Area and the Germany city cluster. Among them, digital talent migrating to the Boston-Washington city cluster and the Sydney Bay Area accounts for more than 57%, while those migrating to Bangalore, the SF Bay Area and the Germany city cluster account for 11%, 10% and 9% respectively of the total outflow outside of the city clusters.

Digital talent from the Germany city cluster migrates mainly to Bangalore, the Boston-Washington city cluster and the UK-Ireland city cluster. Among them, digital talent migrating to Bangalore and the Boston-Washington city cluster accounts for more than 50%, while 14% migrate to the UK-Ireland city cluster, and less than 7% to the YRD city cluster.

Digital talent from the Triple J (Jing-Jin-Ji) City Cluster, the YRD city cluster and the GBA city cluster migrates mostly within China, with very frequent movement among the three regions. Internationally, digital talent from these three city clusters migrates mostly to the Boston-Washington city cluster and the SF Bay Area. Digital talent from the Triple J (Jing-Jin-Ji) City Cluster migrates mainly to the YRD city cluster, the Boston-Washington city cluster and the GBA city cluster, accounting for about 40%, 38% and 22% respectively. Digital talent from the YRD city cluster migrates mainly to the Triple J (Jing-Jin-Ji) City Cluster, the GBA city cluster and the Boston-Washington city cluster, accounting for 34%, 25% and 20% respectively of total outflow. Digital talent from the GBA city cluster migrates mainly to the YRD city cluster, the Triple J (Jing-Jin-Ji) City Cluster and the Boston-Washington city cluster, accounting for 30%, 23% and 17%. In addition, the SF Bay Area is an important destination for digital talent from the Triple J (Jing-Jin-Ji) City Cluster, the YRD city cluster and the GBA city cluster, with talent outflows of 7%, 6% and 6% respectively.

Digital talent from the Sydney Bay Area migrates mainly to Bangalore, the UK-Ireland city cluster and Singapore, accounting for 24%, 23% and 16% respectively. Compared with other city clusters, digital talent outflow from the Sydney Bay Area is relatively scattered and balanced.

Digital talent from Bangalore migrates mainly to the Boston-Washington city cluster and the SF Bay Area, together accounting for 60%. Digital talent migrating to Singapore and the Sydney Bay Area account for an additional 24%.

The destinations for digital talent from Singapore are relatively scattered and balanced, with Bangalore, the Boston-Washington city cluster and the Sydney Bay Area, accounting for 27%, 16% and 14% respectively. Digital talent from Singapore moves frequently to China, with more than 20%

migrating to the Triple J (Jing-Jin-Ji) city cluster, the YRD city cluster and the GBA city cluster.

In conclusion, the Boston-Washington city cluster is a main outflow destination for digital talent moving from other city clusters, but it is a more important inflow source. It is worth noting that compared with the inflow source of digital talents, Bangalore is becoming obviously more important as an outflow destination of digital talents, indicating that Bangalore has become a globally important highland of digital talents.

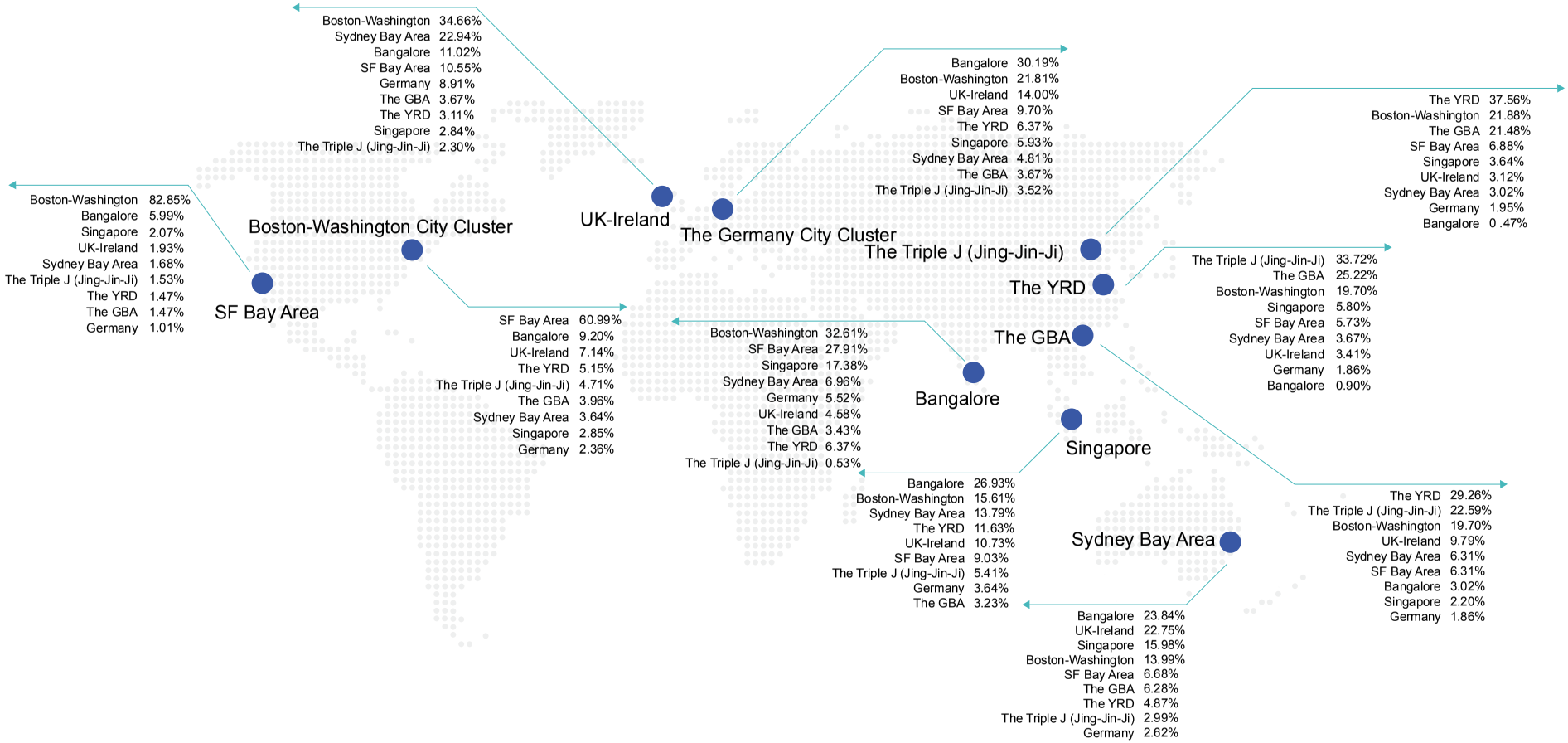

Figure 6.5 Distribution of Digital Talent Destinations among City Clusters

• Chapter Summary •

Among the cities we analyzed, most cities are in digital talent inflow while only a few cities are in digital talent outflow.

The five most attractive cities for digital talent are Dublin, Santiago (Chile), Shanghai, Shenzhen and Bangalore.

Seven cities have more digital talent outflow than inflow, including Beijing, Philadelphia, Guangzhou, Baltimore, Birmingham, Nanjing and Tianjin.

Compared with the migration of digital talent between city clusters, the migration within the city cluster is more active. However, the three major city clusters in China are just the opposite.

Digital talent of Boston-Washington city cluster, UK-Ireland city cluster and Germany city cluster are more likely to migrate within the city cluster than external migration. Boston-Washington city cluster is the most active area for digital talent migration in the world.

On the contrary, China's YRD city cluster, GBA city cluster and Triple J (Jing-Jin-Ji) City Cluster are more likely to migrate between city clusters than within city cluster. In particular, the migration within city cluster in Triple J (Jing-Jin-Ji) City Cluster is only around 15%.

07

Summary and Recommendations

The digital economy is playing an increasingly important role in urban development and has become an important driving force for the growth of city clusters. Cities that are in close geographical proximity can form synergies by leveraging the innovative and industrial advantages of each, thereby enhancing the overall level of digital economic development. The accumulation and migration of talent has played an important role in this process. This research has taken digital talent as the subject of its research and produced in-depth insights into the current status of the digital talent pool in major city clusters and core cities around the world by analyzing and comparing the regional and industry distributions, education background, and seniority in 11 digitally innovative city clusters and 26 core cities in the world's major economies. At the same time, this research further analyzed the profile of digital talent and the migration of digital talent in various city clusters, and expounded in greater depth on the potential and development trends among the digital talent pool. It is hoped that the results of this research will shed additional light on the development of the digital economy in city clusters around the world.

(1) Industry Development

While digital talent is strongly represented in both ICT and non-ICT industries, we observe that the proportion of digital talent in non-ICT industries is higher than that in ICT industries overall. This is a promising indication that digitization is expanding beyond ICT into other industries, including manufacturing, healthcare, finance, corporate services, consumer goods, education, and media and communications. Development between industries is often mutually reinforcing. How to strengthen the investment of resources and funds related to digital technology and digital talents in industries lacking in the digitization process is an issue that needs to be considered in future policy making.

At the same time, we notice that the proportion of digital talent across different industries also reflects the varying economic emphasis of the city that the industries are located in - for example, financial hubs like New York and London have higher proportions of digital talent in the finance industry, while commercial and innovative centers such as Guangzhou and Shenzhen show greater concentration of digital talent in the consumer goods industry. This suggests that the digitization path is closely related to a region’s existing strengths, since it is more efficient to build off existing infrastructure and ecosystems.

(2) Skills Development

Based on LinkedIn’s Skills Genome methodology, we analyzed the representative digital skills of city clusters. We see that each city has its own unique set of representative digital skills and competitive advantages. Looking at the digital skills penetration ratio within each cluster, we also see that cities within a cluster have distinctive traits - for example, in the Boston-Washington cluster, Washington is relatively stronger in cybersecurity while Boston is stronger in robotics.

Skills development in a region is closely related to its existing strengths - building off of success is likely to be more effective than trying to build another ecosystem from scratch, and regions should aim to leverage existing strengths as they continue to grow their talent. Both tech skills and disruptive tech skills are important to the skill development of digital talent, and to the digital innovation and city development. General tech skills relate to the ability of the workforce to leverage and embrace the digital age. Disruptive tech is projected to have a great impact on labor markets in coming years, and achieving the optimal balance between these will be key for embracing the Future of Work.

(3) Migration of Talent

Boston-Washington city cluster is the most important source of digital talent in the world major city clusters. Besides, there is a greater tendency to migrate within one's cluster, or to clusters which are geographically nearer. We also found that the flow of digital talent showed different characteristics in within-region migration and between-region migration. For instance, Boston-Washington, UK-Ireland and Germany-city clusters tend to have more within-region migration, while the clusters in China (Yangtze River Delta, Greater Bay Area and Triple J behave the opposite, exchanging more with digital talent from outside of the regions.

Migration is useful for economic development in many ways. It can help to supplement local supply of talent for high-demand jobs, build global connectivity, and facilitate international knowledge sharing to generate and further innovation. Based on our current analysis, we are seeing a greater tendency for domestic (or at least within-region) migration but not international migration. Policies (e.g. talent exchange programmes) which promote international migration would help to facilitate better global integration, knowledge sharing across borders, and build professional networks that facilitate trade and open new markets.

About Tsinghua SEM Center for Internet Development and Governance (CIDG)

Tsinghua SEM Center for Internet Development and Governance (CIDG), founded in April 2016, was established by School of Economics and Management, Tsinghua University in response to the National Strategy of Reinvigorating China through Network on the basis of the college in the research on Internet economy and management, talent training advantage, and international influence. Committed to leading the digital transformation of China's economy by thought, the center integrates the global resources of top-level experts, makes full use of cutting-edge technologies including Internet, big data, etc., carries out research work focusing on the fields of digital economy, business innovation in the era of global interconnection, digital transformation of Chinese economy, Internet governance, etc., provides objective reference suggestions for improving the scientific decision-making level of government and boosting technology and business innovation and the development of public service, and also constructs the platform for cooperation for promoting the development of digital economy and industrial innovation.

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About LinkedIn Economic Graph

LinkedIn was founded in 2003 and headquartered in Silicon Valley, California, USA, with offices in more than 30 cities worldwide. LinkedIn's mission is to connect the world's professionals to make them more productive and successful. As the world's leading professional network, LinkedIn has more than 645 million members, covering more than 200 countries and regions around the world. In January 2014, choosing " 领英 " as its Chinese name, LinkedIn officially announced its entry into China in order to better connect the Chinese professionals, and to provide a global platform to help them achieve their career aspirations.

LinkedIn's vision is to create economic opportunities for every member of the global workforce, and create the world's first Economic Graph. The LinkedIn Economic Graph is a digital representation of the global economy based on 645M members, 35k skills, 30 million employers, more than 20 million open jobs and 90k educational institutions. With this data, LinkedIn can analyze and predict economic trends, such as cross-regional talent migration and skills gap analysis. These insights will help every member of the global workforce, as well as global policy makers and educational and training institutions, and better connect people to economic opportunity.

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