2018 CHINESE CORPORATE INNOVATION REPORT

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A Win-Win New Era

As China embarks on a new path of development, innovation has become the main driving force and a key feature for the country. In an era consisting of new technologies, new industries, new commercial activities and new business models, corporates face brand-new opportunities like no other time before while meeting subversive challenges in the same way. All the changes have prompted us to continuously explore the meaning of innovation, review its history, and share innovative practices.

Rome was not built in a day, and the same goes for innovation. Regarding the understanding and measurement of innovation, we need to take a rational perspective to analyze the growth of all things. Different to the Chinese saying that "a falling leaf heralds the start of autumn," there is no shortcut for understanding innovation.

The process of innovation is multi-dimensional. Emerging technologies such as mobile internet, cloud technology, and the Internet of Things are shaping and constantly improving commercial fundamentals, which provide a vast imaginative space for innovation, and thus propels the exploration of business models and systems. In this context, we not only pay attention to the innovative theme of technological breakthrough, but also explore how to effectively combine technological innovation with business models and the mechanism of innovation. Finally we aim to present an innovative concerto composed of the trio that can enhance each other's charms and virtues.

The principal part of innovation is also multifaceted. The rise of unicorn companies has the same significance as the transformation and upgrading of traditional industrial corporates for China's economic development in the new era. We can draw inspiration from new products and new commercial activities created by new technologies such as digital economy, smart manufacturing and new energy. We can also be enlightened by the innovative model and spirit from those traditional corporates that have shown tremendous courage in their participation in the next round of the international division of labor and adjustments in industrial structure.

The development of innovation is also multi-structured. Innovation has gradually penetrated every corner of the Chinese economy. When we analyze the status quo of China's economic innovation and

development from a multi-industry and multi-regional perspective, we need to look at regional economic models such as the Guangdong-Hong Kong-Macao Greater Bay Area. The area's powerful vitality and unique ecology can trigger more innovative thinking and offer more practice experience which can be easily promoted.

The market environment is changing rapidly and the industry ecology is constantly evolving. Embrace innovation and be brave in making change. That's a principle for every corporate to survive and develop in this era. In the same way, the financial industry also has to keep exploring how to tackle the new era with innovative attitudes.

At HSBC, we help financial reform by adapting pioneering technologies such as blockchain and continuously improve our service to be "simpler, faster and better." More and more innovative companies have become our partners. In Guangdong and Hong Kong, HSBC established a dedicated team in serving high technology companies, assisting the construction of the international technology innovation center in the Greater Bay Area through a closer linkage of financial services between Guangdong and Hong Kong. We are committed to delivering unique and commercially valuable content. We also pledge to provide corporates with profound insights into the market and cutting-edge industry information, hence we can grow together on the road to innovation.

This is the original aspiration that led to HSBC releasing the first Chinese Corporates Innovation Report last year. This year, we once again joined hands with Yicai and Peking University HSBC Business School to present the 2018 Chinese Corporates Innovation Report. Through extensive analysis and corporate research, we have studied the environment, resources and performance of Chinese corporates and industries for innovation under the latest market dynamics. With a comprehensive interpretation of innovation, we will lead our innovative exploration in the field of financial services and bring new thinking, inspiration and reference to all pioneers on the road to innovation.

Innovation is the primary impetus. As China's economic environment is steadily shaping towards a healthy future, more and more corporates will grow stronger along with the booming market opportunities, relying on their continuous investment in innovation and improvement in production efficiency. HSBC will continue to provide support to corporates with our innovative spirit. Together with our business partners, we will strive to innovate, share experiences and create a win-win new era.

Vice Chairman of Peking University Council,
Dean of Peking University HSBC Business School
HaiWen

Exploring the Origins of Innovation

The famous economist Joseph Alois Schumpeter believes that innovation is key to the realization of effective growth in economy. Without innovation, it does not only restrict the overall economic growth but also makes qualitative leaps in economic development impossible. China has placed “innovation” at the core of its national development as a whole, on top of its current “Five Ideas of Development”. To seek economic development in the current new era, efforts need to be made in order for innovation to promote structural transformation in industrial structure and to accordingly pave the way for new energies, new materials, new designs, new technologies and new products to appear and to ultimately satisfy the needs of people in their boundless pursuit for wonderful life.

Innovation is what spurs up advancements in history and the origin of development of the times. This is a consensus that has been reached in society. The even more important enlightenment from Schumpeter, however, is that: The enterprise is the main-body for innovation and the spirit of entrepreneurs is the main source of innovation. Only innovative activities in an enterprise can really promote the development of the industry and accordingly contribute to constant development in economy to ultimately make a nation wealthy and powerful as well as the people rich. Therefore,, by constructing an innovation indicator system that centers on enterprises to help follow up the status and situation of enterprises in China in innovative development, it is not only conducive for people to understand what are the actual corporate innovations taking place at present, but also help enterprises further explore sources of innovation .

Amidst the innovation wave in current China, Peking University HSBC Business School introduced the 2018 Corporate Innovation Report of China with listed companies as its representative sample in order to keep track of the rules shown in industrial reforms and economic development from the micro-perspective of these enterprises, with particularly important significance and value. The

report helps us correctly understand and address some issues present in our efforts of current innovation to accordingly lay more emphasis on innovation from the source instead of just applying innovation and to also systematically include non-technical innovation systems such as commercial model-based innovation and management-oriented innovation as part of the highly efficient innovation system.

2018 marks the 40th anniversary since China initially started reformand open-up. In the course of speedy economic growth over these 40 years, private entrepreneurs have not only been trend-setters for the era, but also initiators of economic development. As shown by statistics, 17 private enterprises in China have been on the world's Top 500 list so far, 60% of China's GDP is attributed to private economy and more than 80% of workforce is employed in private enterprises. It is not too much to say, private enterprises have contributed significantly both to economic and social developments. As shown by the analysis of data, in the overall system of corporate innovation, the innovation of enterprises marked by different ownerships reflects the heterogeneity in industrial distribution: Central enterprises are competitive in the fields such as aerospace, biomedicine and large or exclusive equipment. Local state-owned enterprises enjoy outstanding levels of innovation in the machinery of electrical appliances and devices while private enterprises are relatively superior in the fields such as information technology-related services and tele-communication -oriented electronic equipment. It can be seen that private enterprises, which play a crucial part in the national corporate innovation system, are indispensable in the overall innovative development of national economy. In 2018, the central government has promulgated a series of measures to energetically support private enterprises in their development. Once implemented, these measures will push private enterprises further ahead with their innovative activities so that enterprises in the new era can gain more vigor and momentum in innovation, further enriching the contents of our Corporate Innovation Report of China t in the future.

Yicai Media Group
General Manager
Chen Sijie

Dancing with Innovation

Studying innovation in this day and age carries significant implications.

In reality, innovation is the most effective means of unraveling all types of economic problems throughout the history of humanity. Innovation is the key to an entirely new level of understanding.

Yet innovation as a concept has never been properly explained. Since as soon as a concept is defined, it would be a product of the past. Economists have been attempting to find the nature of innovation, but they have only managed to see clearly its silhouette as it breezes past in the blink of an eye.

Joseph Alois Schumpeter has a more persuasive description of innovation. Innovation involves the study or introduction of new products, application of new technology, exploring new market, use of new raw materials, or establishing new form of production and organization. This open-ended description involving exhaustive list leaves infinite possibilities for the reader. In the year of 2018 can those of us in China provide more examples of practice and theory to allow others to more clearly capture the 'dance-steps' of innovation?

In this report, one will see many examples of corporate innovation. They clearly show how new materials, technologies, products and markets are being assembled to provide the drive for sustained upgrading and growth of enterprises. The report also explore, from the perspectives of industry and territory, the impact of various key factors on innovation in an attempt to identify its rhythm.

This year's report also devotes considerable attention to Guangdong, Hong Kong and Macao Greater Bay Area, giving an analysis of various economic and social possibilities in the increasingly close city cluster in the near and long term. This is a timely and highly visionary study. The flow of key resources in the region fostering growth may well be a new mode of economic innovation and growth in China. In this regard, the practice in the Greater Bay area may have wide-ranging values and inspirational meanings.

Nevertheless, innovation has never been targeted at any single aspect in the future. Accompanying it are economic transformation and industry reforms. Insofar as the pace of innovation is blistering, any transformation and reform would likely be devastating for some. The report also focuses on transformation and reform of the region and industries, leaving the records of their cross-section.

This era is forging ahead along such cross-sections.

With regard to some of the current problems in global economy, I believe that solutions would be found through innovation. In its 40th year of reform and opening up, China should take a pragmatic approach and become the provider of innovative solutions. This would be highly beneficial.

The future would be well worth looking forward if people 'dance' in tandem with innovation.

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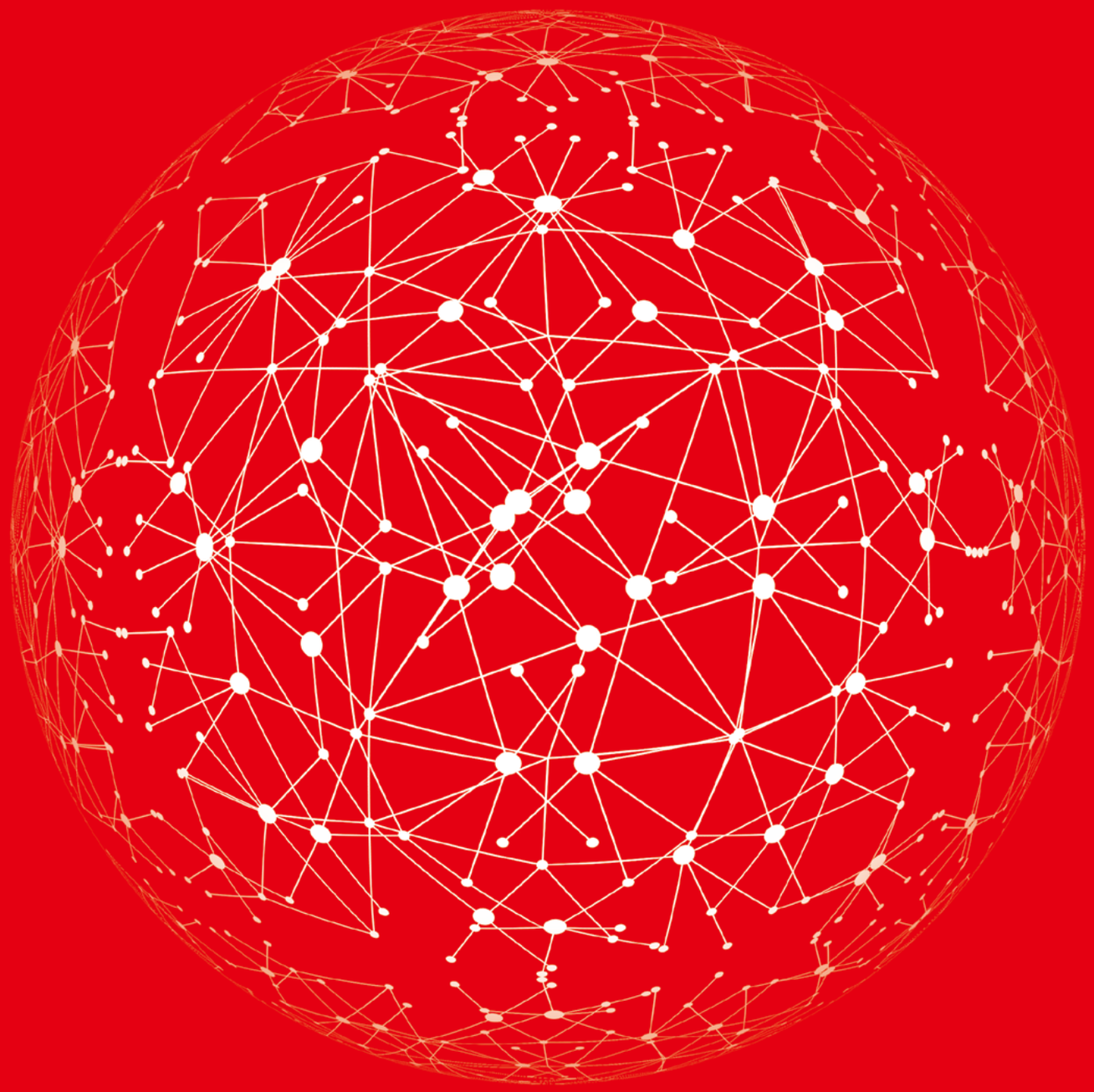
Chapter 1
China Corporation Innovation Index

P07-015

A corporation is the main entity for innovation. Evaluation of a corporation's innovation is always a core content for studies on innovation.



China Corporation Innovation Index

A corporation is the main entity for innovation. Evaluation of a corporation's innovation is always a core content for studies on innovation. An outstanding evaluation method for corporate innovation will not only more accurately reflect the existing status but will also provide guidance on how to drive such innovation.

"Corporation Innovation Index" (CII) has been created by Peking University HSBC Business School with a view to establish a systematic evaluation method with respect to the study of existing state of corporate innovation in China. It combines analysis of currently-available key assessment methods with characteristics achieved by corporations in specific innovation practice.

1.

About key assessment methods on corporate innovation

Innovation assessment systems have been formulated by international bodies, government units, scientific research organizations for global, regional, national and provincial science parks. Examples include Global Innovation Index, China Innovation Index, Independent Innovation Capability Evaluation Index and China Enterprise Sustainability Index (see Figure below on comparison between key innovation indexes).

However, scientific research and expert consultation has concluded that several common problems exist in these indexes:

The first problem is that businesses do not form the core of study subjects. The majority of innovation indexes tend to use global, regional, national and provincial science parks as study subjects. They hardly use corporations as the basis for constructing innovation indexes. For prevailing corporate innovation indexes their tendency is also to focus on enterprise sustainability and not innovation in order to evaluate their innovation capability and level.

Secondly, the assessment perspective tends to be single-minded. Traditional assessment indexes focus on technical innovation displayed in facilities, activities and products, but overlook innovation with respect to skills management, trademark and branding and business models. In fact, these aspects are easily overlooked.

Thirdly, assessment tends to be subjective. Most of the indexes rely greatly on experts' subjective opinions. This is reflected in the probability of data culled from practices being affected by different study methods, which in turn affect the objectivity of their assessment results. Subjective valuation is carried out on the index in question during assessment with weight assigned in order to obtain final ranking. But as subjective valuation provides no detailed

explanation on such index, it is difficult to ensure the assessment's objectivity.

The fourth issue is the limitation of the sample population. Data in existing assessment indexes are predominantly those concerning regional innovation. As such they are inadequate in reflecting the level of innovation by corporations. In addition, data used are often from more than a hundred corporations in China's Top 500, data from businesses in science parks and those from small, provincial-level medium and micro enterprises. Such data are limited in nature and do not adequately explain the overall standard of innovation by Chinese businesses.

2.

China Corporation Innovation Index

CII, created by Peking University HSBC Business School, is aimed at addressing key problems in existing evaluation methods for corporate innovation. It is a more systematic tool for the study of current status of innovation by Chinese businesses. The following are some of its key features:

Firstly, the assessment subjects for CII are listed Chinese companies. Such companies represent the overall standard of corporate and national innovation in China, and compared with other systems which utilize regional entities as assessment subjects for innovation, is more persuasive. Computation of corporations' capacity for innovation can reflect such capacity and allows decision-makers to extract as much information as possible. It is possible, based on the regional distribution of corporate innovation, to show the entire region's innovation capacity. It facilitates one's ability to have a grasp of the current status

	01		02	03	04	05	06
Comparison of Key Innovation Indexes	Global Innovation Index		Knowledge Economy Index	Independent Innovation Capability Evaluation Index	Zhong Guancun Index	Enterprise Innovation Capability Evaluation Index	China Enterprise Sustainability Index
Publisher	Cornell University, WIPO, INSEAD		World Bank	China Economic Monitoring and Analysis Center, National Bureau of Statistics of the People's Republic of China	Beijing Municipal Bureau of Statistics, Beijing Academy of Social Sciences, Zhong Guancun Innovation and Development Research Institute, Beijing Fangdi Economic Development Research Institute	Ministry of Science & Technology	China Enterprise Confederation, China Business Council for Sustainable Development
Measurement Index	A System B Human Capital C Infrastructural Facilities D Market Maturity E Business Sophistication F Output of Knowledge and Technology G Output of Invention Nature Appropriate Adjustments to Indicators for Sub-Items		A Human Capital B Knowledge Capital C Regional Economic Output D Knowledge Sustainability	A Potential Technological Innovation Resources B Technological Innovation Activities C Capacity for Technological Innovation D Technological Innovation Environment	A Innovation Environment B Innovation Capability C Industry Development D Corporate Growth E Sphere of Influence F Internationalization Secondary Indicators 38 Sub-Item Indicators	A Capacity for Innovation Input B Capacity for Synergistic Innovation C Intellectual Property Capacity D Capacity for Drive by Innovation 12 Secondary Indicators 24 Tertiary Indicators	A Core Competitiveness B Resource Environment C Society 8 Secondary Indicators 68 Sub-Item Indicators
Assessment Method	Expert opinion plus general research		Weighted according to expert opinion plus general research	Weighted according to expert opinion plus general research	Aided by experience in compilation of "Silicon Valley Index"	Official statistics and expert research	Weighted according to expert opinion plus general research
Research perspective and degree	Innovation Competitiveness Globally		Innovation Soft Power Globally	Independent Innovation Capability National Level	Science Park Innovation Development Industrial park	Technological Innovation Capability Enterprise Level	Sustainable Development Enterprise Level
Research Characteristics	High level of regulatory conformity and reliable processing methods		Universality, considers innovation from perspective of knowledge	Emphasis on "independent"	Correspond with territorial characteristics	Highly conforming, comprehensive	Emphasis on green development
Research shortcomings	Excessively macro in approach with limited meaning for corporate innovation		Information coverage is comparatively weak	Limitations on research from perspective of technological innovation	High-tech industry in Zhongguancun – Limitations in the scope of evaluation	Emphasis on technological research and output	Barely a hundred businesses selected, thus limited research sample

Table 1-1

Model of China Corporation Innovation Index

●Primary Indicators	●Secondary Indicators	●Source and Projection
Innovation Environment	Shareholding Structure	Wind (obtained from calculation)
	Innovation Enthusiasm	Google Search (statistics)
	Government Efficiency	Reports from Beijing Normal University
Innovation Resources	R&D Investments	Wind (directly obtained)
	R&D Personnel	Wind (directly obtained)
	R&D Intensity	Wind (weighted projection)
Innovation Performance	IP Level	SIPO and China Trademark Net (weighted total)
	Level of Intangible Assets	Wind (directly obtained)
	Sales Profit Margin	Wind (directly obtained)

Note: The Table is compiled based on the ternary assessment system of Innovation Assessment by UNDP consisting of "Environment-Resource-Performance".

of corporations throughout the region and adjustment of economic distribution.

Secondly, 3 indicators namely shareholding structure, enthusiasm for innovation and government efficiency have been added to the assessment system. General assessment is then carried out on the corporation's innovation environment at three levels: characteristics of internal decision-making, social innovation environment and government service standard. Two other indicators are also added. They are IP standard and intangible assets, the former being utilized to describe a listed company's innovation competitiveness while the latter describes its performance with respect to innovation. New-economy corporations are reclassified according to the products of their principal operations in order to facilitate assessment of new economic characteristics, thereby examining such corporations' acts of innovation.

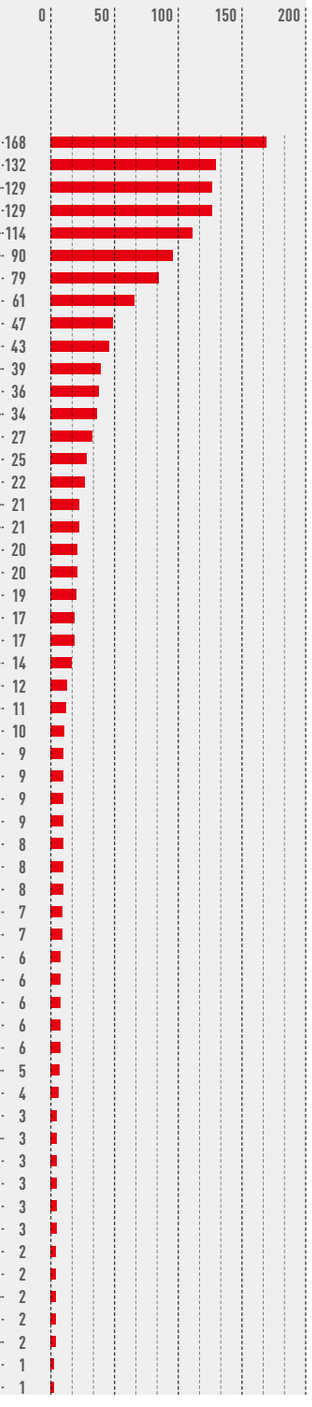
Thirdly, the assessment system takes into consideration European Innovation Scoreboard, the Silicon Valley Index (U.S.) and National Innovation Index Report (published by the Academy of Science & Technology for Development) while relying on United Nations' entrepreneurship policies and organization innovation policy assessment indicator. They are then combined with the characteristics of Chinese innovation to create an assessment index that contains 9 secondary indicators over three aspects namely innovation environment, innovation resources and innovation performance, for Chinese corporations.

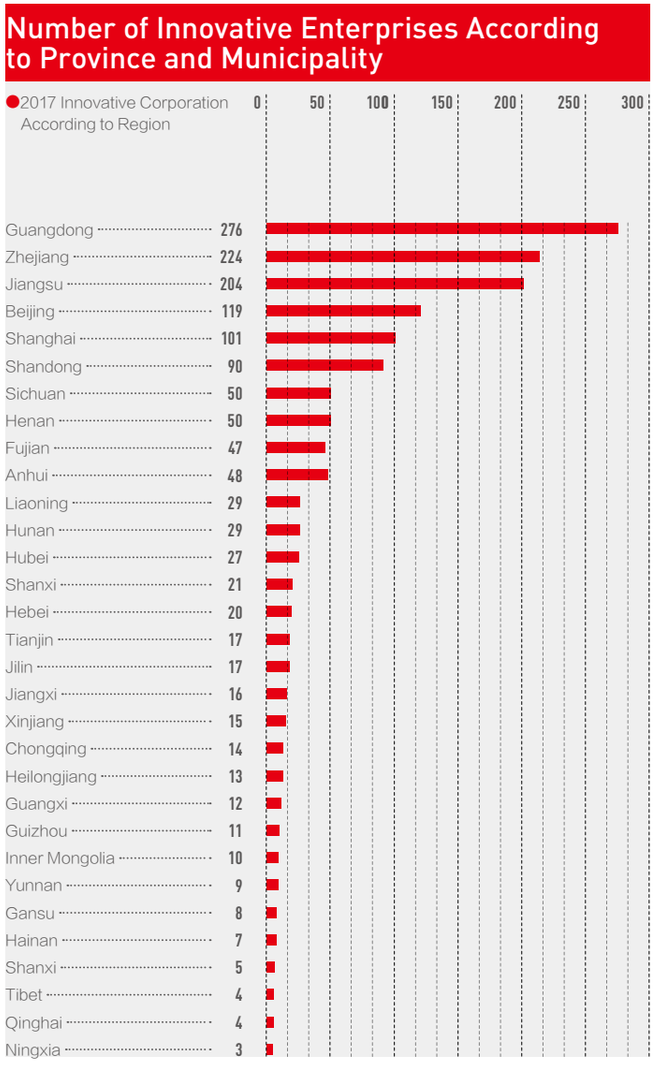
Fourthly, the assessment system analyzes data from 3,541 companies listed on Shanghai and Shenzhen Stock Exchanges. After eliminating those with no investments or output in research and development, the remaining 1,500 corporations are used as samples and assessed. Compared to past research that collected data only from Top 100 Chinese companies, enterprises in science parks and provincial-level small, medium and micro enterprises, the assessment system is more wide-ranging and persuasive.

Note: Industry classification is based on the standards issued by CSRC.

Number of Innovative Enterprises According to Industry Category

●2017 Corporate Innovation Capability According to Region





Note: Industry classification is based on the standards issued by CSRC.

3.

Quantification Method for Core Indicators

Innovation Environment Indicator

Innovation environment consists of three indicators: internally the corporation's shareholding structure and externally innovation enthusiasm and government efficiency.

Shareholding structure: Differences in corporate governance structure and corporate operation between corporations with different shareholding structure will be ultimately reflected in their innovation performance. Through analysis of a corporation's shareholding structure such as the degree of concentration of its shareholding[2], it is possible to compare the innovation environment and levels of different corporations.

Innovation enthusiasm is based on results generated by search engines using key words including "year, company name or stock name, innovation" for listed companies to obtain and collate data on the public's following of innovation by listed companies for the period 2015-2017.

Data on government efficiency are obtained from "Top 100 Prefecture-level City Governments for Efficiency" in the "Chinese Local Government Efficiency Study Report" for the years 2015-2017 compiled by Beijing Normal University. They are supplemented by corresponding provincial government efficiency data or neighboring prefecture-level city government data.

Innovation Resource Indicator

Innovation resource consists of three indicators namely investments in R&D, R&D personnel and R&D intensity. Investments in R&D and R&D personnel correspond to the sections on "R&D Expenses" and "number of R&D Staff" in listed companies' reports. The intensity of R&D can be divided into two categories, namely "R&D Intensity_Expenses (R&D Investment/Operating Revenue)" and "R&D Intensity_Personnel (R&D Staff/Total Number of Employees)". The R&D intensity used in the research is the average value of R&D Intensity_Expenses and R&D Intensity_Personnel.

Innovation Performance Indicator and Data Source

Innovation performance consists of IP level, level of intangible assets and sales profit margin.

IP level: A corporation's IP level is the weighted total of the volume of its "patent disclosure volume" and "trademark application volume" during the past 3 years. The level of its intangible assets[3] is its intangible assets as a percentage of its total assets. Sales profit margin [4] is its total profit after tax as a percentage of its operating income.

4.

Generation of Indicator Weightage

Selection of Weight

As CII is a multi-indicator assessment system, it is sure to face the problem of combining multi-indicator systems into a single index. The main way of addressing this problem is to weight each indicator before combining all of them. To more accurately assess and compare innovation development by corporations under different innovation environment and resource conditions, this Study utilizes weight average method on the respective indicators and raw data after standardizing them to give identical weight under all three dimensions, before calculating their standardized value and ranking under different assessment indexes. This allows for comparison of corporations with respect to their innovation development and level under different regions, ownership structure and innovation fields.

5.

Scoring

The score for innovation environment [6] is based on shareholding structure, innovation enthusiasm and government efficiency. The score for innovation resource [7] is based on investments in R&D, R&D staff and R&D intensity. The score of innovation performance [8] is based on IP level, level of intangible assets and sales profit margin.

The final innovation index [9] is generated based on a combination of all three scores. When calculating the scores of the final innovation index, each indicator undergoes dimensionless quantification without prior removal of the industrial average.

6.

Scope of Study Samples

We have used listed Chinese companies as study subjects to evaluate the current status of innovation in China. Their industries include manufacturing, services, agriculture, husbandry and fishery and cover 56 major categories with companies in 31 provinces in China. In all 1,500 companies have been assessed, with each company having invested in R&D and achieved innovation output. All data for the period 2015-2017 are complete. We have also equalized some of the extreme values during the past 3 years.

02

Chapter 2
Current Situation in Regards to Innovation for Chinese Enterprises

P016-029

Private enterprises have become the main force of innovation,
and communication electronics,
special purpose machinery and home appliances have become the main innovation sectors.

Current Situation in Regards to Innovation for Chinese Enterprises

1.

Individual Characteristics of Innovation in Chinese Enterprises

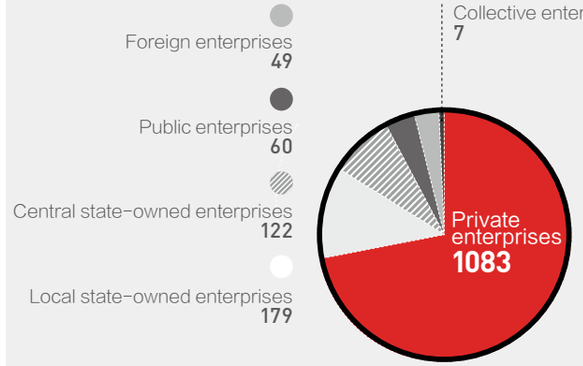
To assess the individual characteristics of innovation of listed companies in China, we analyze the detailed state of innovation in China from the perspectives of the power of innovative actors, innovative sectors, stock market, ownership, different manufacturing sectors and different service sectors.

Private enterprises have become the main force of innovation, and communication electronics, special purpose machinery and home appliances have become the main innovation sectors

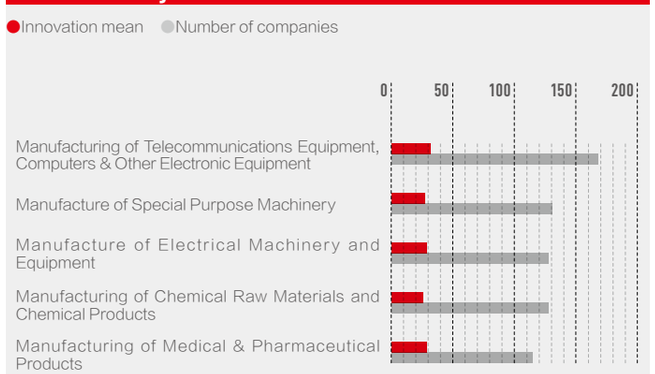
Private enterprises have become the main actors for innovation. Based on the number of companies with different ownership status, the 1083 private enterprises account for 72.2% of the samples; 301 state-owned enterprises of central and local governments account for 20.06% of the samples; 67 public and collective enterprises account for 4.47% of the samples; 49 foreign enterprises account for 3.27% of the samples.

Electronic communication, special purpose machinery, home appliances, manufacturing of chemicals, and manufacturing of medical &

Number of listed companies based on different ownership status



Number of listed companies and innovation capacities in the five major innovative sectors in 2017

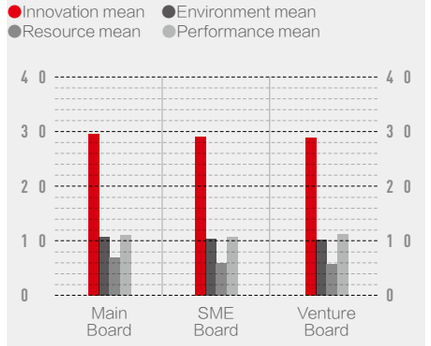


pharmaceutical products constitute the five main innovation sectors. Each of the five major innovation sectors has more than 100 listed companies. They total 672 companies and account for 44.62% of the samples. Among them are 168 computer, communication, and other electronic equipment manufacturing companies with an innovation mean of 32.21 which places them on top in terms of innovation in the five major innovation sectors; 132 special purpose machinery manufacturers have the innovation mean of 28.86; 129 electrical equipment and equipment manufacturers and 129 manufacturers of chemical raw materials and chemical products have innovation means of 29.54 and 25.62, respectively; 114 manufacturers of medical & pharmaceutical products have the innovation mean of 27.36.

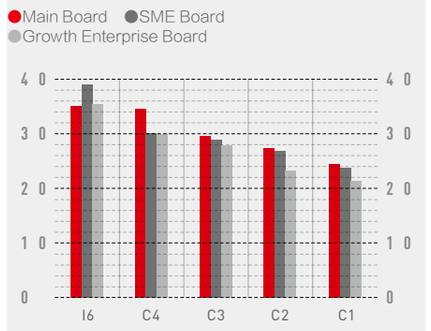
The scale of main board companies has significant impact on corporate innovation and companies on the small & medium enterprise board and the Growth Enterprise Board have strong innovation capacities in the Internet and software information technology sectors.

The scale of main board companies has significant impact on their innovative power. In terms of the innovation rankings, main board companies have the best performance with an innovation mean of 28.81. In terms of individual indicators, main board companies perform the best in terms of innovative environment and resources while Growth Enterprise Board companies stand out in their performance in innovation. Specifically, main board companies have outperformed companies on the small & medium enterprise board and the Growth Enterprise Board in the C1 light manufacturing, C2 light manufacturing, C3 heavy manufacturing, and C4 precision manufacturing sectors. Companies on the small & medium enterprise board and the Growth Enterprise Board have higher innovation capacities than main board companies in the I6 Internet and software information technology sectors. Main board companies dedicate more resources to innovative sectors based on the scale of their companies and advantages in financing to achieve higher innovation capacities. Companies on the small & medium enterprise board and Growth Enterprise Board exhibit strong innovation capacities due to the superior environment in the I6 Internet sector and competition between private companies.

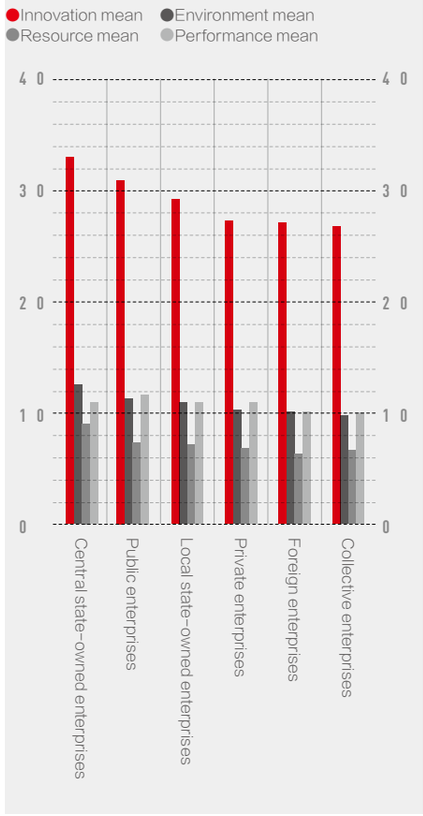
Innovation capacities of companies on different boards in 2017



Distribution of industries based on innovation capacities of companies on different boards in 2017



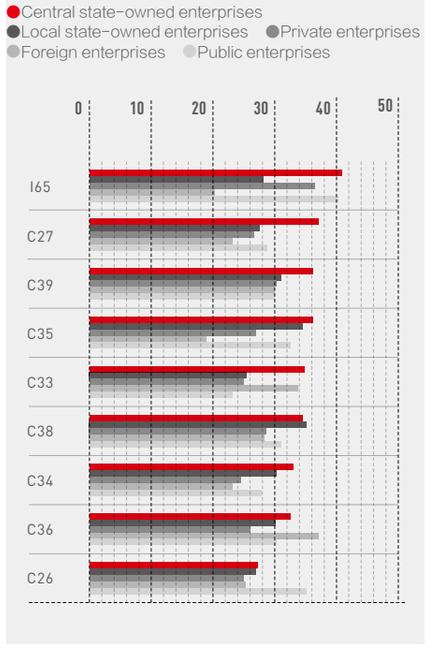
Innovation capabilities of companies with different ownership status in 2017



Central state-owned enterprises have stronger overall innovation capabilities and other subsidiary enterprises have stronger innovation capabilities in specific sectors

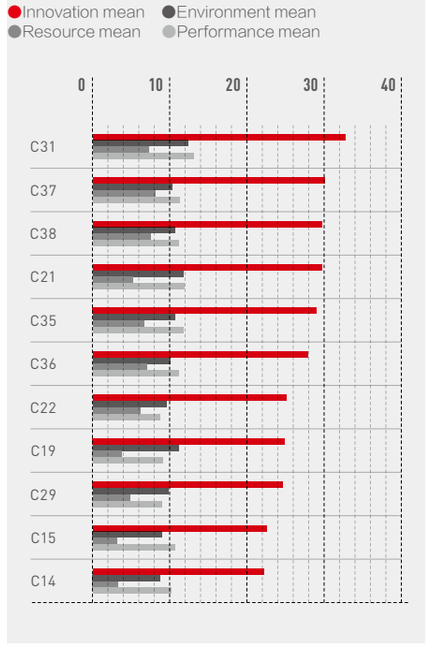
Among the company categories based on ownership structure, central state-owned enterprises have the strongest innovation capabilities. Based on individual indicators, central state-owned enterprises rank first in innovative environment and resources while public enterprises rank first in innovative performance. Foreign enterprises rank last in terms of innovation resources. Specifically, central state-owned enterprises have achieved higher levels of innovation in the manufacturing of medical & pharmaceutical products, manufacturing of metal products, manufacturing of general purpose equipment, manufacturing of special purpose machinery, telecommunications and electronic equipment, and innovation technology services. Local state-owned enterprises have achieved higher innovation standards in the electrical machinery and equipment manufacturing industry. Private enterprises had outstanding performance in innovation in information technology services and telecommunications and electronic equipment. Foreign enterprises have achieved higher innovation standards in the automobile manufacturing industry. Public enterprises have achieved higher innovation standards in the manufacturing of chemical raw materials and chemical products. We believe that as central state-owned enterprises receive more government services and support and they enjoy advantages in innovation resources, they have higher overall powers for innovation. Other subsidiaries have achieved their current high innovation capabilities due to local support for industries, competition between companies, or early opening of the industry to foreign investment.

Comparison of innovation capabilities of companies with different ownership status in 2017



Note:I65 is the software & information technology service industry; c27 is the manufacturing of medical and pharmaceutical products; C39 is the manufacturing of computers, telecommunications equipment and other electronic equipment; C35 is the manufacturing of special purpose machinery; C33 is the manufacturing of metal products; C38 is the manufacturing of electrical machinery and equipment; C34 is the manufacturing of general purpose equipment; C36 is the automobile manufacturing industry; C26 is the manufacturing of chemical raw materials and chemical products.

Innovation capabilities of companies in different manufacturing sectors in 2017



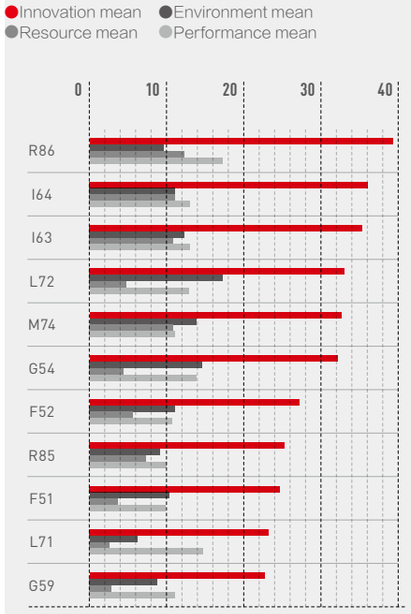
Note: C31 is the smelting and pressing of ferrous metals; C37 is the manufacturing of railway, shipbuilding, aerospace and other transportation equipment; C38 is the manufacturing of electrical machinery and equipment; C21 is the manufacturing of furniture, C35 is the manufacturing of special purpose machinery; C36 is the automobile manufacturing industry; C22 is the manufacturing of paper and paper products; C19 is the manufacturing of leather, fur, feather and related products and footwear; C29 is the manufacturing of rubber and plastic products; C15 is the manufacturing of wine, beverages and refined tea; C14 is the food manufacturing industry.

Heavy industries have higher innovation capabilities while light industries such as the manufacturing of furniture may achieve breakthrough first

Heavy industries have stronger innovation capabilities than light industries. In the heavy industries, the innovation mean of smelting and pressing of ferrous metals as well as railroads and transportation equipment manufacturing exceeded 30 while the innovation mean of the manufacturing of electrical machinery and equipment, special purpose machinery, and automobile manufacturing exceeded 27. In the light industries, with the exception of the furniture manufacturing industry with an innovation mean of 29.03, other industries such as the manufacturing of paper and paper products and food processing have the innovation mean below 26 which signify low innovation capabilities.

Heavy industries have outperformed light manufacturing industries in terms of their performance in innovative environment, resources, and innovation performance. All heavy industries have scored 10 or more for an innovative environment. Among light industries, only the manufacturing of furniture and footwear have scored more than 11 in environment scores while the scores of other light industries were lower than 10. The scores for innovative resources in electrical machinery manufacturing, transportation equipment manufacturing, and automobile production were higher than 7 while the scores for innovative resources in light industries such as the food production, leather goods, and footwear were lower than 4. Heavy industries have achieved an innovative score of higher than 11 while light industries such as paper making, manufacturing of rubber and plastic products, leather goods, and footwear scored less than 10.

Innovation capabilities of companies in different service sectors in 2017



Note:
R86 is radio, television, film and audiovisual recording & production; I64 is Internet & related services, I63 is telecommunications, broadcasting television & satellite transmission services, L72 is commercial services; M74 is professional scientific & technical services; G54 is road transmission services; F51 is wholesale trade; F52 is retail trade, R85 is news and publishing; L71 is leasing; G59 is warehousing.

Modern service industries have stronger innovation capabilities while innovation in traditional service sectors must be strengthened

In terms of the ranking of innovation capabilities, modern service industries have stronger innovation capabilities while traditional service sectors have weaker innovation capabilities. Among modern service sectors, radio, television, film and audiovisual recording and production exhibit the strongest innovation capabilities with an innovation mean of 39.34. Internet and related services, commercial services, and professional scientific & technical services have higher innovation capabilities and innovation mean of more than 33. Among traditional service sectors, road transportation sector has stronger innovation capabilities with an innovation mean of 32.06 due to state investments in transportation infrastructure. Retail, news and publishing, wholesale, and warehousing have lower innovation capabilities and innovation mean of lower than 28.

Compared with traditional service sectors, modern service sectors enjoy superior innovation environment, more abundant innovative resources, and higher innovation performance. The commercial service sector has the best innovative environment with an average score of 17.72. Radio and audiovisual recording & production, Internet & related services, and professional scientific & technical services have more abundant resources for innovation and they have an average score of more than 10. Radio, television, film and audiovisual recording & production ranked first in terms of performance in innovation with an average score of 17.31. It demonstrates that the industry has created more intellectual property rights and economic benefits.

2.

Characteristics of Innovation in Chinese Enterprises in the New Economy

New economic industries are divided into 5 sectors including new Internet, smart industries, biotech and pharmaceuticals, culture and innovation, and environmental protection industries according to the classification of Shenzhen's Strategic Emerging Industries and the methodology in "Beijing City New Economic Activities Classification" and based on the main products of listed companies in 2017 and their industry classification in the new economy. The classifications are used to evaluate the innovation capability of enterprises in different industries in the new economy and their differences in innovative environment, resources, and performance.

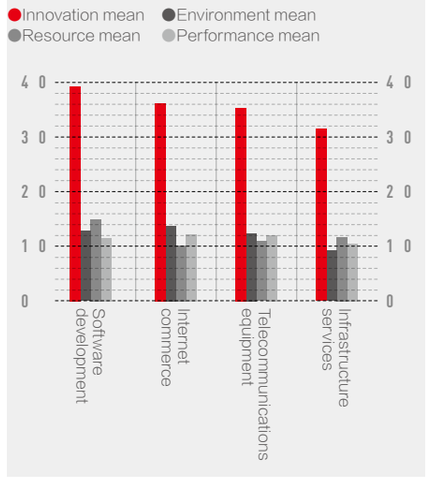
Research has shown that innovation of enterprises in the new economy is based mainly on market forces. Resources are invested into applications and they result in increased innovation in Internet applications, smart commercial applications, and innovation in the new economy. The lack of investment in resources for basic research has weakened innovative forces in basic services for the new Internet, smart production, new energy businesses, biotech and pharmaceuticals production, and original innovation in the manufacturing sector of the new economy.

Overall, **the new economy exhibits growth mainly through market forces and resources are concentrated in the application level. The new economy lacks original innovation capabilities and lacks investment in technological research and development.** The conditions are exemplified in "four strong industries, four weak industries, and one industry with low-level development".

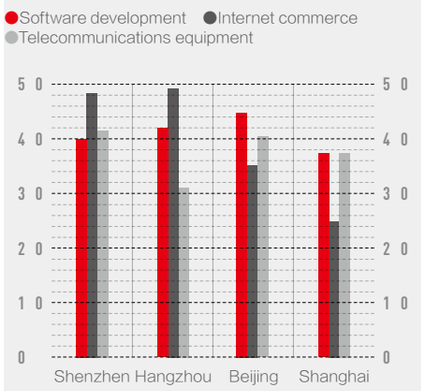
Companies offering new Internet applications and services exhibit strong innovation capabilities and infrastructure service companies exhibit weak innovation capabilities

There is a total of 102 new Internet companies that encompass four sectors including software development, Internet businesses, telecommunications equipment and infrastructure services (e.g. data centers) The innovation mean is 36.67 which is higher than average and demonstrates stronger overall innovative power in the industry. In terms of rankings for innovation capacities, software development companies have the strongest innovation capacities while Internet businesses follow in the second place, telecommunications equipment manufacturing in third, and Internet infrastructure services rank fourth.

Innovation capacities of new Internet companies in 2017



Regional distribution of innovation capacities of new Internet companies

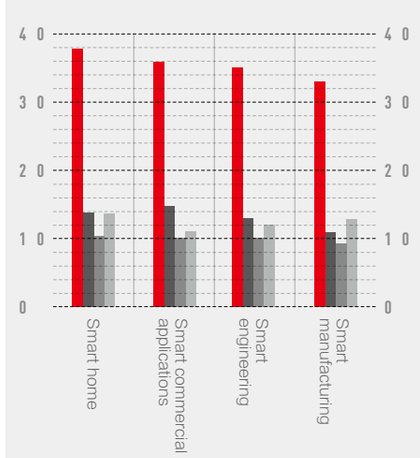


Note: As data for Internet infrastructure service companies of certain regions were not available, they were not included in the comparison of innovation capacities of new Internet companies.

In terms of individual indicators, Internet businesses scored the highest in innovative environment and innovative performance, software development scored the highest in resources, and telecommunications equipment and infrastructure services companies obtained lower scores in all indicators. This shows that focusing on market applications and improving the level of professional services play important roles in advancing the innovation performance and standards of Internet companies, particularly those that pursue applications.

In terms of regional innovation capacities, new Internet companies in Shenzhen exhibit the strongest corporate innovation capacities while other cities rush to catch up. Shenzhen has the strongest innovative power in software development, Internet commerce, and telecommunications equipment sectors. Hangzhou has strong innovation capacities in software development and Internet commerce. Beijing has strong innovation capacities in software development and telecommunications equipment sectors. Shanghai exhibits overall weaknesses. This illustrates that although new Internet application services exhibit higher overall innovation capacities, the innovation capacities in the telecommunications equipment industry in different cities are stronger than those of software development or Internet commerce.

Innovation capacities of companies in smart sectors in 2017



Companies offering smart applications and services exhibit strong innovation capacities and smart manufacturing companies exhibit equipment weak innovation capacities

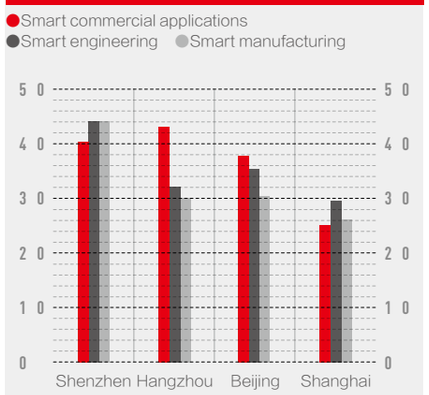
A total of 87 companies are included in smart industry and they provide smart home, smart commercial applications (e.g. smart terminals), smart manufacturing (e.g.

industrial robots), smart engineering (e.g. smart transportation), and other smart products and services. In terms of their ranking in innovation capacities, smart home, smart commercial applications, and other companies that offer smart applications and services have high innovation capacities while smart engineering, smart manufacturing, and other smart businesses exhibit weaknesses in innovation. In terms of individual indicators, companies that offer smart commercial applications and services have the best environment for innovation while smart home appliances manufacturers have the strongest capacity for resources and innovative performance. By comparison, smart engineering and smart manufacturing companies have weaker innovation environment and resources. In conclusion, companies providing smart application services have superior environment for innovation. They value investment of resources for innovation and achieve higher levels of innovation.

In terms of regional innovation capacities, smart application companies in Shenzhen exhibit the strongest corporate innovation capacities while other cities exhibit strengths in specific areas. Companies that provide smart applications in Shenzhen have scored higher than 40 for innovation capacities in individual sectors and the smart manufacturing and smart engineering companies have achieved higher levels of innovation than companies that offer smart commercial applications. This shows that Shenzhen has a group of listed smart companies with the strongest original innovation capacities. Beijing and Hangzhou exhibited outstanding performance in smart commercial applications and smart engineering companies in Shanghai outperformed companies that provided smart commercial applications and services in terms of innovation.

▶ Note:
As data for smart home companies of certain regions were not available, they were not included in the comparison of innovation capacities of smart companies.

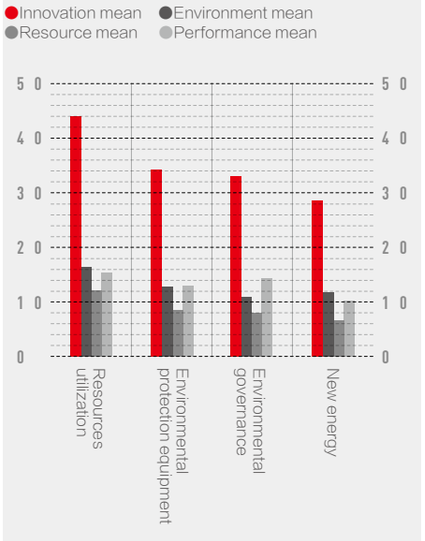
Regional distribution of innovation capacities of companies in smart sectors



Resources utilization companies exhibit strong innovation capacities and new energy companies exhibit weak innovation capacities

A total of 35 companies are classified as green environmental protection companies. They include resources utilization (recycling industrial waste as resources for reuse), environmental protection equipment manufacturing, environmental governance (e.g. green landscaping services), and new energy businesses. The innovation mean is 32.48 and it exceeds the innovation levels of non-green environmental protection companies. Among them, resources utilization companies exhibit the strongest innovation capacities with an innovation mean of 43.79 which helps increase resources recycling efficiency and reduces pollution. New energy companies have lower levels of innovation with an innovation mean of 28.46, demonstrating the companies' weaknesses in green energy development. In terms of individual indicators, companies that recycle resources scored higher than other green environmental protection industries in innovative environment, resources, and innovative performance. Companies that provide environmental governance services scored lower and new energy companies have lower scores for resources and innovative performance. In conclusion, green environmental protection companies should improve the innovation environment, expand investment in resources for innovation, and increase innovative performance.

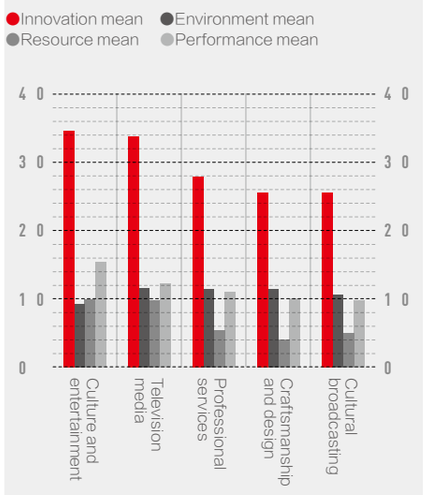
Innovation capacities of green environmental protection companies in 2017



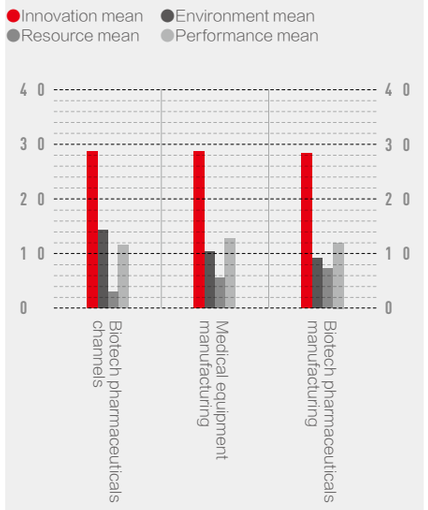
Culture and entertainment companies exhibit strong innovation capacities and culture broadcasting companies exhibit weak innovation capacities

A total of 33 companies are classified as cultural and creative companies and they include culture and entertainment (e.g. online games), television media, professional services (e.g. exhibition services), craftsmanship and design, cultural broadcast (e.g. publishing). The innovation mean is 30.23 which is 1.78 higher than the innovation mean of non-cultural and creative companies. Among them, cultural and entertainment and television media companies exhibit strong innovation capacities with the innovation mean of 34.76 and 33.86, respectively. Craftsmanship design and cultural broadcasting companies have weak innovation capacities and their innovation means were 25.66 and 25.64, respectively. In terms of individual indicators, television media companies have the best innovative environment and cultural broadcasting companies have inferior innovative environment. Culture and entertainment companies have more resources for innovation while companies providing professional services, craftsmanship and design, and cultural broadcasting have less resources for innovation. Culture and entertainment companies have the best performance in innovation while culture broadcasting companies exhibit the weakest innovation capacities. Cultural and creative companies require additional improvements for their innovation capacities. They should increase investments in cultural broadcasting, craftsmanship and design, and other cultural infrastructure to increase the level of their services and the influence of their brand.

Innovation capacities of cultural and creative companies in 2017



Innovation capacities of biotech and pharmaceuticals companies in 2017



Biotech and pharmaceuticals companies achieved low levels of innovation overall

A total of 49 companies are classified as biotech and pharmaceuticals companies and they encompass three sectors including biotech pharmaceuticals channels, biotech pharmaceuticals manufacturing, and medical equipment manufacturing. Their innovation mean is 28.29 which is 0.21 points lower than non-biotech and pharmaceuticals companies. It means that biotech pharmaceuticals companies desperately need to improve their overall innovative levels. In terms of individual indicators, biotech pharmaceuticals channels have the best innovative environment and biotech pharmaceuticals manufacturers have the worst innovative environment. Biotech pharmaceuticals channels, biotech pharmaceuticals manufacturing, and medical equipment manufacturing companies have lower scores in innovative resources. it demonstrates an overall lower level of investments in resources for the biotech pharmaceuticals industry. The medical equipment manufacturing sector has the best innovative performance. The biotech and pharmaceuticals industry especially biotech pharmaceuticals manufacturing industry should improve their innovative environments and expand investments in innovation resources to resolve the current weaknesses in innovation of the biotech and pharmaceuticals industry in China.

3.

Trends of changes

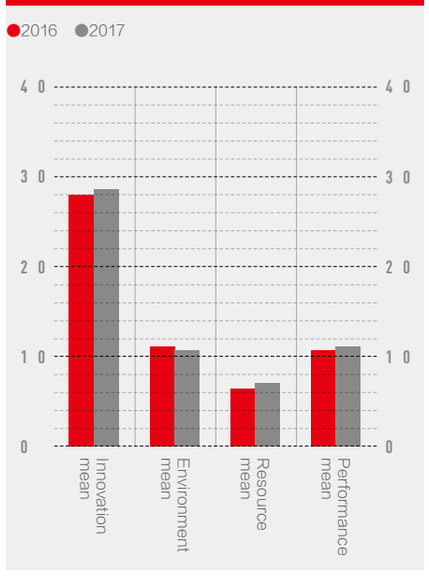
We have specifically compared the statistics from 2016 against those from 2017 in hopes of finding more information on innovation in China in order to evaluate the characteristics of innovation of listed companies in China.

Improvements achieved in innovation levels, innovation resources, and innovation performance as gaps between regions widen.

The listed companies sampled in 2016-2017 have shown improvements in innovation levels, innovation resources, and innovation performance. Compared to 2016, the innovative score of listed companies rose by 0.41 in 2017 mainly due to companies' increased investment of resources for innovation and improvement of innovative performance value. Specifically, listed companies' scores for resources increased by 0.72 in 2017, representing an increase in companies' investment in resources. The innovation performance score of listed companies increased by 0.27 in 2017, representing an increase in the value of companies' innovative technologies and businesses.

The innovative environment score dropped from 11.07 in 2016 to 10.48 in 2017 mainly due to an increase in the gap of the efficiency of local governments. In conclusion, as companies continue to expand investment in innovation and improve innovative performance, local governments should be encouraged to provide companies with equalizing public services.

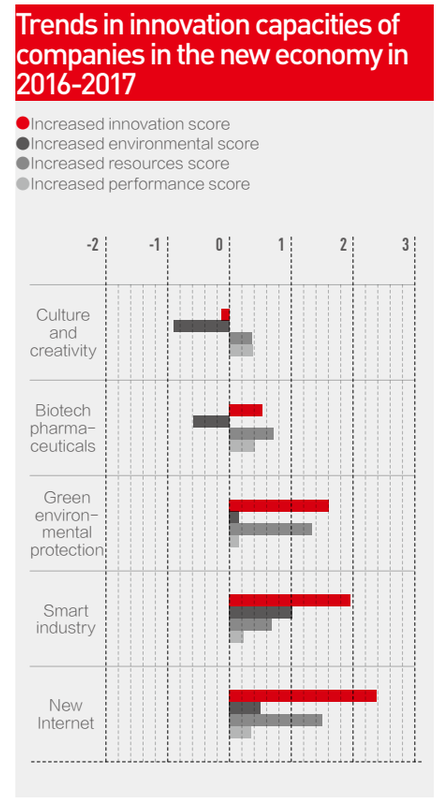
Comparison of companies' innovation capacities in 2016-2017



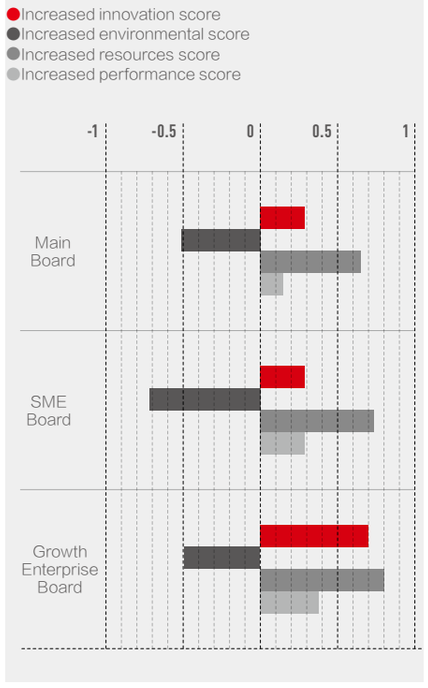
New Internet and smart industries take the lead while cultural and creative companies suffered the greatest decline in innovation capacities

Industries in the new economy with faster growth in innovative scores have improved in innovative environment, resources, and innovative performance. Mobile Internet industry is the industry with the fastest growth in the new economy while innovation in the cultural and creative industry has declined substantially. In terms of individual indicators, mobile Internet companies retain their relative advantages in resources but the smart industry and green environmental protection industry are catching up in investment in innovation. This illustrates how certain companies are gaining awareness of the importance of increased investments for companies' innovation. The smart industry has achieved greater growth in its innovative performance score and it illustrates the fulfillment of the value of innovation by companies in the industry when they focus on smart applications and the market. It also actively advances improvements in companies' innovation.

Trends in innovation capacities of companies in the new economy in 2016-2017



Trends in innovation capacities of companies on different boards in 2016-2017

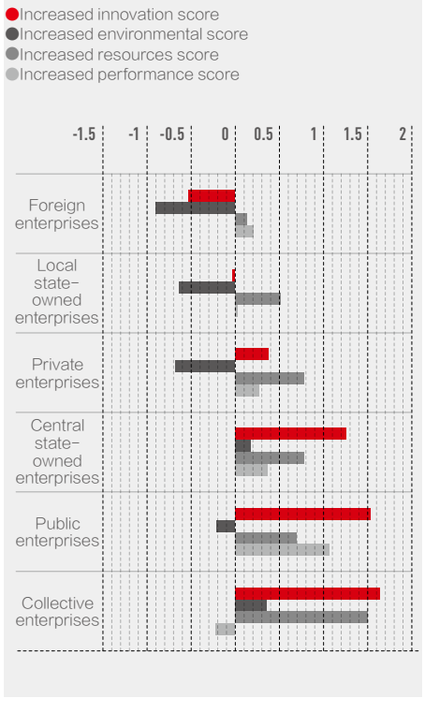


Note: "Increased innovation score" refers to the innovation mean in 2017 minus the innovation mean in 2016 by companies in certain categories (based on classification in listed boards and ownership). The same calculation method also applies to the increased environmental score, increased resources score, and increased performance score.

Growth Enterprise Board companies achieved Significant improvements in innovation capacities and small & medium enterprise board companies must improve their environment for innovation

Board companies with significant improvements in innovative scores mainly achieved improvements due to investment in resources for innovation and improvements in innovative performance. Compared to 2016, Growth Enterprise Board companies' innovative scores increased by 0.7 in 2017 which was higher than the average increase of 0.2 of main board and small & medium enterprise board companies, representing a significant increase in the innovation capacities of Growth Enterprise Board companies. Growth Enterprise Board companies increased their resources score and performance score by 0.8 and 0.38, respectively and the scores contributed to significant improvements in innovation. Small & medium enterprise board companies have achieved higher increases in their resources and performance scores than main board companies but they scored lower in innovative environment than main board companies. This has led to a balanced state in the increase in innovative scores between small & medium enterprise board companies and main board companies.

Trends in innovation capacities of companies with different ownership structures in 2016-2017



Investment of resources for innovation and increase in innovative performance are the main driving forces for growth in innovation.

Companies with different ownership that have significant improvements in innovative scores mainly achieved improvements due to investment in resources for innovation and improvements in innovative performance. Based on the increased scores for innovation, collective enterprises, public enterprises, central state-owned enterprises, and private enterprises have increased their innovative scores by 1.63, 1.53, 1.26, and 0.36 in 2017 compared with levels in 2016. In terms of individual indicators, collective enterprises, central state-owned enterprises, private enterprises, and public enterprises have increased their resources scores by 1.52, 0.78, 0.77, and 0.70. They have also increased their performance scores by -0.22, 0.34, 0.26, 1.07. These statistics illustrate that the enterprises' improvement of innovation levels was mainly due to increased investment in research and development and improvements in innovative performance. It is worth noting that the innovation levels of foreign enterprises dropped from 27.92 in 2016 to 27.39 in 2017 as the increased resources scores and increased performance scores were insufficient for making up for the declines in increased innovation scores and increased environmental scores.

03

Chapter 3
Innovative Business Case

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Innovation by Cainiao: The primary role of innovation is solving problems

In anticipation of T-Mall's yearly Double 11 sale, Cainiao Network and Unilever recently initiated a strategy of smart supply chain upgrading.

New retail is required to have a rapid and precise response to consumers' needs. This brings both challenges and opportunities to businesses. If they knew where the buyers for their products were, they would be able to dynamically optimize their supply chain and achieve lean management, better serving consumers.

This was a key reason for Unilever to initiate its smart supply chain upgrade strategy in partnership with Cainiao. The aim is to achieve "precision for each type of products down to its granularity" with respect to sales forecasts, production plans, inventory-replenishment plans and smart sorting by using a big data chain such to optimize inventory, reduce

costs and increase efficiency.

It is never easy to achieve this result as it requires the integration of online and offline systems, as well as an ability to accumulate, analyze and process big data.

Nonetheless, this is what Cainiao has always done. Before the establishment of Cainiao, no similar type of company existed in the logistics sector either at home or abroad. One can say that the operation and business model of Cainiao is a form of innovation.

1.
Driving industry digitization

Although it focuses on logistics, Cainiao is not a courier company.

Jack Ma had unequivocally positioned the company even before its inception as such: What a courier company can do, Cainiao will not do. What it cannot do or is unable to do at present, Cainiao will do. The ultimate aim is to enhance efficiency, reduce costs and improve the user experience.

Therefore, since the day it came into being, Cainiao has sought to solve the problems of efficiency and costs traditional courier companies and merchants face through technological innovation. Its objective is to digitize the industry.

The electronic delivery bill is a result of such technological innovation. Under Cainiao's drive, the top 15 courier companies in China now all use electronic delivery bills. This means that mainstream courier delivery companies that claim over 90 percent of China's e-commerce market possess IT capability for their delivery business.

Delivery bills are courier forms to be filled in when ordering delivery services. Previously paper-based delivery bills are customized by different courier companies. As such there is no standard format. E-commerce operators had no choice but to link to their existing ordering systems, often at high cost. Furthermore, as paper-based order forms were not accompanied by data platforms, courier companies were required to manually enter key information - another high cost factor - causing the courier sector to be unable to achieve smart information management.

Since 2014, Cainiao has partnered with dozens of mainstream courier companies and launched an electronic delivery bill system that can automatically connect shippers, courier companies and recipients and capture data and information on key routes. Using data from connected delivery bills, it is possible to optimize the delivery chain. In addition, using electronic delivery bills has improved sorting efficiency by more than 50 percent.

Other examples abound of applying digital technology to help the express trade improve its efficiency. These include logistics warning radars which provide logistics data forecasts and warning during peak seasons such as Single's Day. Smart routing bills allow precise sorting to improve the operating efficiency of courier companies.

On the eve of this year's Nov. 11 sales, Cainiao announced its online video cloud surveillance system 'Sky Eye Program.' This move means millions of video cameras in logistics premises all over China would no longer act merely as surveillance systems for retrospective viewing, but will upgrade to smart, cognitive devices able to identify idle vehicles and determine whether loading and unloading work is carried out properly and whether premises are filled with goods in such a way as to clutter passageways.

What used to require manual inspection can now be done real-time by video cameras and information can be instantly forwarded to control desks for immediate response by deploying staff. Deppon is the first to use the IoT-based logistics system on a trial basis. It has been estimated that circulation efficiency within the courier stations has improved by 15 percent since. It is expected to save nearly CNY10 million per year.

"You would have noticed that in the past few years - even during Nov. 11 - logistics has picked up its pace. It is now almost impossible to hear about operators being unable to cope with orders. This is because we have conducted significant advance data analysis and forecasting with our partners. It is now possible to achieve precision with respect to the volume of orders and the number of vehicles allocated for a particular route," Cainiao Network Vice President Wang Wenbin said. Before, he did not know how many parcels needed to be delivered, let alone how many were to be delivered from Zhejiang to Beijing.

2.
This is not a technology company

During the past few years, Cainiao has always hoped to forecast goods' sales volume and purchasers through analyses and intelligent algorithms using data from T-Mall's Nov. 11 logistics data to improve delivery efficiency.

AI analysis of historical data enables forecast of sales volume of popular products in different cities, while pre-loaded warehouses make forecasts to place goods in depots closest to consumers. Today such pre-loaded warehouses can be found in all tier-one and tier-two cities.

Many of these warehouses are either built or rented by Cainiao. With respect to the current state of affairs - many merchants have indicated that the logistics, warehousing and operating capability of traditional distributors significantly trails demand under new retail - Cainiao's smart logistics network is now connected to 30 million square meters of warehousing capacity globally. Thus, Cainiao is not merely an internet technology company. It is also building a significant number of infrastructural facilities.

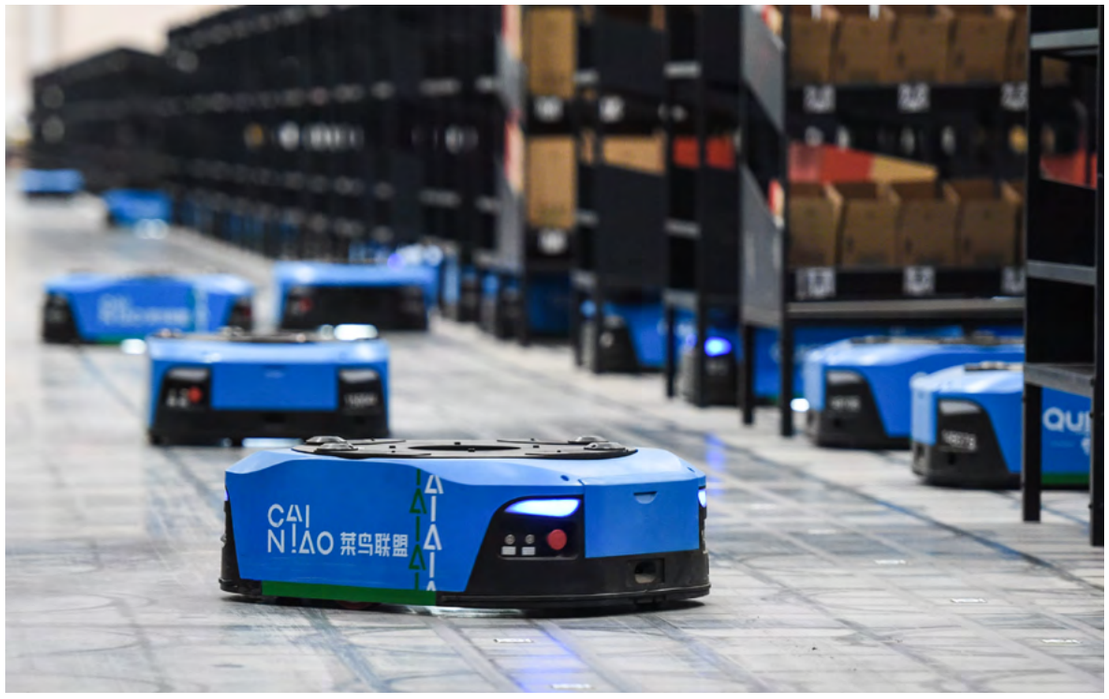
As the scale of its warehousing capacity expands, Cainiao also hopes to inject intelligent DNA into it: Using robots to improve sorting efficiency, and enabling hubs at key locations to be more intelligent. At present, automatic sorting and sorting by robots have been achieved in dozens of warehouses.

Nearly 700 robots are deployed in Cainiao's warehouse in Wuxi Future Park - currently the largest in China - with robotic capability. Inside the nearly 30,000 square meter warehouse, nearly 700 sorting robots form a busy intelligent transport and work system. They automatically evade each other and are self-charging.

In addition, intelligent equipment like the warehouse being taller than a 7-story building, high-speed sorting machines and mechanical arms, which are replicated in many logistics parks in China, enable Cainiao to achieve intelligent management and automatic order-production.

Smart equipment carries the goods into the warehouse, while robots automatically store them on shelves. When goods are sold, the robots automatically locate and pull them.

In September, Cainiao and YTO Express jointly announced the commissioning of their super robot sorting center in the YTO



Express Hangzhou sorting center. In peak periods 350 robots inside a premises of 2,000 square meters work day and night, sorting more than 500,000 parcels each day. The distance the robots cover in three days is that of a trip around the Earth once.

The robots transport parcels to their corresponding sections according to requirements. Upon reaching designated locations, a pallet on a robot activates to release the parcels into apertures. The parcels are sent along a slide from the second floor to the first, where they are packaged. The entire process takes slightly more than 10 seconds. Parcels, sent in volume to 300 different destinations every day are efficiently sorted using such equipment.

This is part of Cainiao's IoT strategy announced on May 31 this year. The company is currently joining hands with the logistics sector to promote the application of IoT technology. It aims to achieve real-time online operation of numerous key logistics elements - including robots - and to realize intelligent deployment, optimizing resource configuration while improving efficiency and reducing costs.

"Cainiao has a team of professionals dedicated to handling robot-deployment technology. In essence this is the same issue as that for AlphaGo," said Cainiao Senior Technical Expert Li Jianjun. "AlphaGo is able to defeat human players because of its exceptional ability to predict events. Cainiao's algorithm allows every robot to possess powerful predictive ability. AI and IoT technologies are then used to realize intense and simultaneous work by multiple robots, and plan the best transit route in advance. In this regard, resources are optimized and crashes are prevented to achieve great efficiency during transportation. "

3.

Three networks for cross-border e-commerce operators

For Cainiao, the logic of innovation is to solve problems, whether to improve the efficiency of the logistics industry, reduce costs or enhance the user experience. Yet today it has begun to study how to buy and sell goods on a global basis through innovation.

The traditional cross-border logistics chain typically consists of long routes and numerous steps. Even when parcels have been sent, logistics information can barely follow. To attain real-time tracking of parcels is thus difficult, and all vendors and consumers are made to wait.

There is also no customer service system for traditional cross-border logistics, and often small and medium enterprises do not know who to approach when problems arise. Add to this issues like slow distribution and poor experience and it is apparent that traditional logistics is unable to meet the needs of small and medium vendors in international trade.

Two years ago, Cainiao began partnering with commercial logistics companies. Together they developed dedicated logistics lines at various locations globally. Several upgrades have also gone through. Cainiao and its partners have also been looking for warehouses worldwide.

Cainiao has launched more than 300 logistics routes in the US and Europe, connecting over 230 cross-border warehouses. It hopes to build three futuristic networks - global parcel transportation network, global supply chain network and global terminal network.

Take Ali Express - Alibaba Group Holding's online trading platform for the global market - where logistics information is visible real-time, thus allaying fears of misplaced goods. A dedicated customer service system means vendors need no longer link with a logistics provider. The platform will make corresponding payment for refunds for logistics reasons.

In addition to helping small and medium enterprises take their first steps outward, Cainiao is also helping international vendors bring goods into China in an accelerated manner. For example, its new global supply chain service enables vendors' upstream suppliers to take orders for shipments to major ports in China.

Cainiao's next step is to continue to develop its commercial logistics solutions. It will help small and medium enterprises participate in global trade by developing overseas warehousing, sea and air freight trunk routes, construct overseas terminal facilities and accelerate promotion of intelligent logistics networks in key markets.

During this time, it would appear to be particularly important to have the capacity to integrate various private resources for them to operate under standard rules.

"Cainiao currently has more than 3,000 employees, of whom more than half are technical staff. We are therefore a synergistic network. How then should we build a network that possesses greater strength than an individual logistics company? There are no precedents for this. Every operation and every exploratory step will demand innovation on our part," said Niu Zhijing, head of Cainiao Network's market public relations.

Horizon: Union of software and hardware in the era of artificial intelligence

"PEOPLE WHO DEVOTE THEIR TIME TO SOFTWARE SHOULD ALSO BUILD THEIR OWN HARDWARE."
– ALAN K, WINNER OF TURING AWARD

1.

If existing tools do not work, then create ones that do.

This is the typical thinking of a scientist.

After leaving Baidu Dr. Yu Kai, founder of the Institute of Deep Learning and chief executive of Horizon Robotics, founded an artificial intelligence chip company.

Baidu and Google were among the first to apply deep learning in the internet sector. Their experts were the first to realize computing efficiency would form a bottleneck in the field's growth.

"When developing algorithms for AI deep learning, Baidu had foreseen that computing by GPUs would be inadequate." Yu realized that if one were to push large-scale applications for AI, one would have to combine software with hardware to truly enhance computing efficiency.

July 2015 saw the incorporation of Horizon with Yu as a main founder. Two years later, Horizon launched its embedded AI-vision chips which were based on its dedicated BPU (Brain Processing Unit). They were the 'Journey 1.0' chip for smart driving and 'Sunrise 1.0' for smart cameras. There is a paragraph in Horizon's corporate introduction that goes like this: Horizon possesses world-class ability to develop deep learning, decision-making and deduction algorithms, in addition to integrating them with high-performance, low-power, low-cost embedded AI smart processors, as well as software and hardware platforms.

"Integrated software and hardware is a strategy that we have adopted right from the beginning. This has never changed," Yu, said, adding, "from the perspective of a person who deals only with hardware, the integration of software with hardware is a puzzling thing. My background is in software, so when I founded a hardware company, it bore the genes of software-hardware integration."

2.

The trend is toward closer software-hardware integration in the AI era. The most effective way to seize on this shift is to have a company that does both at the same time.

Software and hardware need to work together in synergy, but this requirement varies in different eras and with differing carriers. This has led to competition between industries.

During the personal computer (PC) era, the main competition was between Apple and the 'Wintel' alliance of Intel and Microsoft. Ultimately, Apple's hardware and its closed system could not withstand a fight with the Wintel alliance's powerful ecology.

By the time mobile internet came along, the competitors became Apple's 'Series A chips + iOS and the AA (Android and ARM) alliance. Mobile devices rely mainly on battery power. They have higher power consumption than personal computers. It is precisely for this reason that Apple's OS and chips for mobile devices have a distinct advantage with respect to user experience, and this advantage is more obvious than in the PC era. Though the AA alliance currently enjoys a greater market share, Apple has a bigger profit margin.

The synergy between software and hardware will only intensify with the dawn of the AI epoch.

"Software and hardware will integrate ever more in the AI era. The most effective way is for both software and hardware to be handled by a single company," Yu said, "Horizon will produce operating systems and chips for robots in tandem."

As the demand for data and AI increases over the next five to 10 years, demand for AI-related cognitive computing will exceed that for existing logic computing, and AI smart chips will become the mainstream in the chip market, in Yu's view. Companies which can produce AI chips which truly combine software and hardware will thus hold a competitive advantage.

That said, it is never easy for a chip company to truly combine the two. Not only must it possess exceptional capacity for software and algorithm innovation but it also must have world-class experts capable of creating from the ground up original hardware core structure. More important is that the work-flow processes for hardware and software designs are entirely different. The challenge of combining them - in depth, no less - is simply staggering in extent.

"It is highly challenging for many companies in their attempts to achieve synergy for software and hardware research and ensure coordination in their project planning," Yu said.

Horizon is not any different from other companies in that it faces as great a challenge in the fusion of the two. It is just that the company is better able to handle it.

Google is the only company which has currently truly achieved software-hardware integration, in Yu's belief, apart from Horizon and Mobileye, a company that Intel recently acquired. The last company is an Israeli producer of a visual system that safeguards passenger safety and reduces traffic accidents.

3.

Edge computing is fast emerging, making software-hardware integration more important than ever

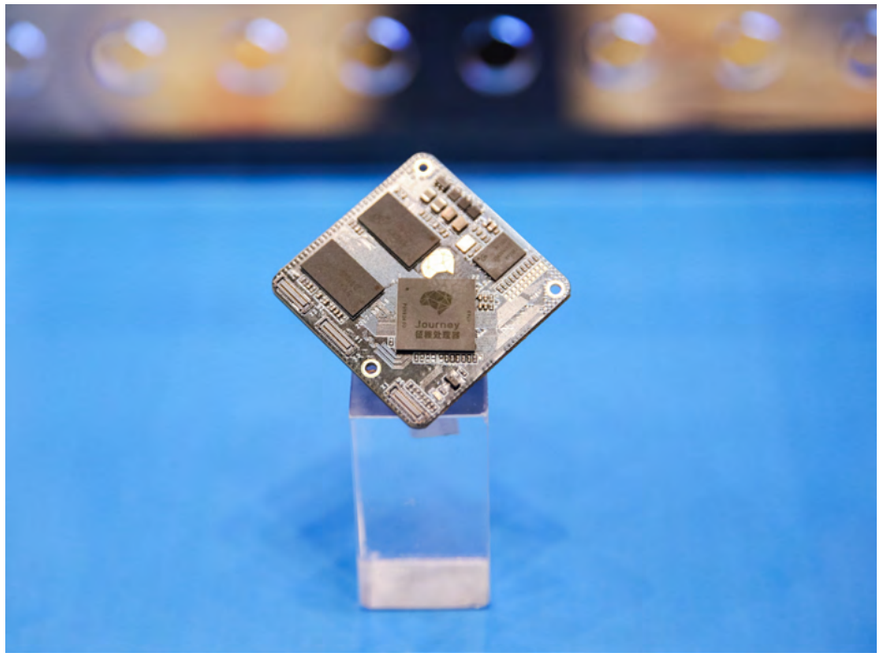
If one were to classify companies such as ARM, NVIDIA and Horizon along the lines of 'logic computing' vs. 'cognitive computing' and 'server' or 'terminal,' one would discover that Horizon would sit squarely within the 'cognitive computing + terminal' class.

	Server	Terminal
Logic computing	Intel	ARM
Cognitive computing	NVIDIA	Horizon

In addition to being positioned for the transition to AI-related cognitive computing, Horizon also pitches itself according to market capacity and its uniqueness.

Computing will shift from central processing to the edge as mobile computing evolves into Internet of Things, which will be the era of the emergence of edge computing (where data are processed at the nearest edge that corresponds with central or cloud computing.) In Yu's view, edge computing will ultimately share the market with central computing. This means that despite its existing modest market share, edge computing will develop rapidly. Furthermore, in contrast with the cloud computing market which established industry giants have dominated, entry into edge computing is relatively easy.

Horizon's ability to integrate software with hardware gives it a distinct advantage in edge computing. The benefits of this integration are reflected in their power consumption and the real-time nature of computing. Although integrated software-hardware is important at the server end, power consumption is only an operating cost since servers are normally connected to a power supply. Furthermore, computing at the server end can be delayed, and there is no extraordinary demand for real-time computing. The situation is completely different for terminal devices. Battery-powered devices are more efficiency-sensitive, and have greater demands in real-time nature of computing (e.g, the real-time response of an autopilot chip can directly affect driving



safety). As such they need better software-hardware synergy.

4.

Artificial general intelligence: Terminal devices - from cognitive computing to integrated cognitive decision-making

Future terminal AI chips will shift from cognitive computing to a model of integrated cognition and decision-making. This is a problem that needs to be addressed for artificial general intelligence. In 2018 Horizon set up its Artificial General Intelligence Lab in the view that change will emerge within the next five to 10 years.

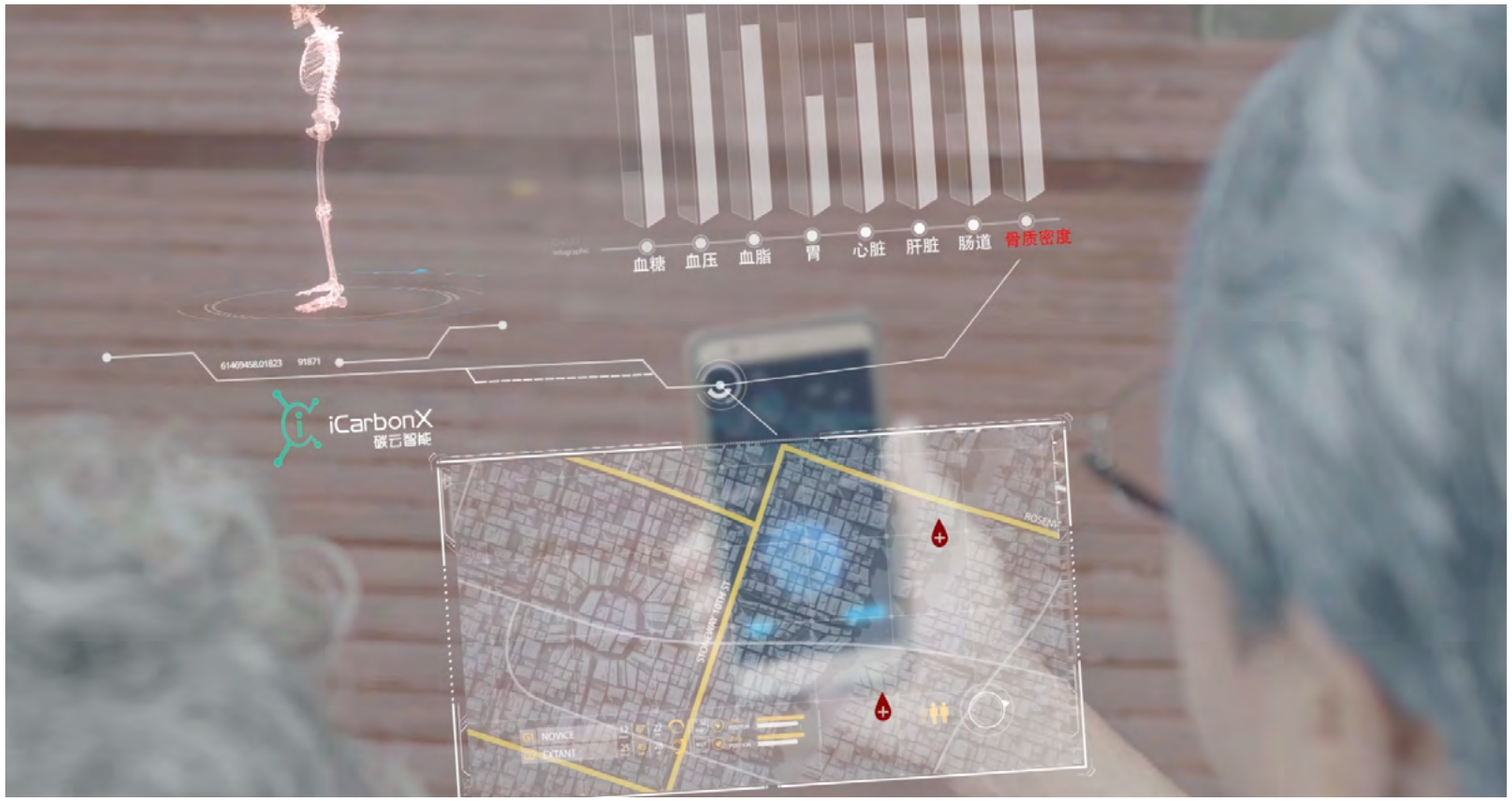
At present, deep learning mainly focuses on cognitive computing. To transit to artificial general intelligence, reinforcement learning (this is a study of how a specific target can be achieved through a series of sequential decision-making steps, and is thus an objective-oriented learning and transfer learning) would require a previously-trained model deployed in another task. These are critical to truly large-scale application of AI. A machine is required to transit from passive training to active learning.

For example, how does one preserve safety in self-driving situations? Safety cannot be tested under normal road conditions. Tests must be under extreme conditions and in unexpected situations. Extreme conditions are those unavailable in training data. Autonomous vehicles must learn to properly deal with situations they have never encountered before, and this is impossible using data training.

"It is essential to transit from existing big data training methods to this type of self-deduction and decision-making method." Yu said, "this is precisely why we set up the Artificial General Intelligence Lab with such significant investment."

For a company like Horizon to be able to emerge from such seminal changes unscathed is probably a matter of life and death.

iCarbonX: A Grand Business Alliance



Wang Jun designed a simple neural network algorithm while still studying at Peking University in 1992. No instructions were given to the machine on how or what it would do, but after evolving over several hundreds of thousands of generations ,the 'bug' learned to become a predator, and behaved as those in nature do.

In 1999, Wang Jun and Wang Jian, another co-founder of BGI Online (formerly Beijing Genomics Institute) took part in the Human Genome Project, becoming the pioneers of genetic testing in China. BGI Online subsequently became China's largest high-throughput sequencing service provider. In 2015, Wang resigned from his post as chief executive of BGI Online - a company that institutions were clamoring to invest in given its unlimited potential - to found iCarbonX.

Wang believed he had accomplished his mission at BGI Online and wanted to understand, having deciphered the code for living things (their genes), to the living program. He wanted to use machine learning to simulate the human body, and find the silicon-based genes for the computing world using the carbon-based genes of the living world.

1.

Looking at life from God's perspective

Carbon refers to carbon-based life. Carbon is known to be a component element for all living things on the Earth. It plays a fundamental role in the DNA, cells and fat in our body. Cloud represents new technologies driven by cloud computing and artificial intelligence. They are the origins of iCarbonX's Chinese name.

To iCarbonX, human beings live in a digital world. Everyday data help us to make rational decisions: What to buy, which music to listen, which news to read, and which route to take. Yet we remained bewildered by life itself, perhaps because of how little we know about genes. This could even be a congenital trait. Life is dynamic, and we know very little about the changes that constantly take place inside us. Take major diseases for example. How do they ultimately re-rear their ugly heads after subsiding within us? How will the health options that we make daily affect our lives?

To truly understand life, one would need a rules-based system that understands the cycle of life and death issues. It would be one that is akin to AlphaGo Zero, only considerably more complex. The system generates silicon-based genes based on your carbon-based genes and delivers them in data format, telling you your existing blood glucose level, and the type of environment in which it is easier to catch a cold, and the probability of you contracting an illness at a certain age. One can then take precautionary measures against major illnesses and order customized health services.

This is a system that understands life; it is also a digital map of life. "Our belief is that carbon-based life can be digitized and digital life can be made intelligent. Ultimately an intelligent digital life can be networked. We believe that when all elements of life are integrated in an unprecedented manner, the secrets of life itself will be revealed." This is a brand-new path in the eyes of the people at iCarbonX, one on which others can gain a fresh perspective on health and life.

If it were to be realized, mankind would be able to ultimately understand itself from 'God's perspective' and manage life itself.

2.

Rendering life digitally does not merely mean a breakthrough in a company's technology. It requires a system that does that.

Rendering life digitally is an extraordinary undertaking. A company's technology cannot possibly hope to drive the process. It would take an entire system to do so, an alliance as it were.

In a commercial society nothing is more secure in relationships than a shareholding structure. Judging by the corporate history of iCarbonX since its inception, its founders had never thought that they would do this alone.

In 2016, iCarbonX announced the acquisition of Israeli AI company Imagu Vision Technologies, followed very quickly by the set up of iCarbonX-Israel AI Research Center. The move was barely one year after iCarbonX's founding. Imagu itself formed in 2005, developing technologies that combine knowledge in different fields in order to support object recognition in many disparate areas such as to alleviate the problem of identifying complex objects. Its image

identification technologies are widely used in the medicine, medical imaging, semiconductors, national security and e-commerce sectors. When acquiring the company, Wang had said that the digital life ecosystem being developed by iCarbonX could only be made possible through the joint effort of top-notch biotechnology and AI teams. Then in the same year, iCarbonX became a strategic investor in Prajnasys, a Shenzhen-based company that provides insurance big data services.

In 2017, iCarbonX completed its Round-A fundraising. Its investors include internet behemoth Tencent Holdings, stem-cell giant VCANBIO and UEC Group, a data center solution and IT service provider.

Early in 2017, the Digital Life Alliance was founded, its members include iCarbonX, SomaLogic, HealthTell, PatientsLikeMe, AOBiome, GALT, Imagu and Tianjin company Robustnique. On behalf of the Alliance, iCarbonX ecosystem invested about USD400 million in all seven companies.

The Alliance collects data on genomics, proteomics, metabolomics, transcriptomics and immune reaction and combines them with analysis of various indicators including intestinal flora and lifestyle for the establishment of a data information library. It then uses algorithms developed by iCarbonX to analyze such complex data.

"I have always been deliberating about AI, but Wang Jun has made my thinking clearer and more precise," said Larry Gold, founder and chairman of Alliance member SomaLogic.

At that time, SomaLogic had already announced its ability to detect nearly 4,200 proteins in the human body. Another Alliance member, HealthTel,l uses silicon chips to detect antibodies and conducts in-depth disease assessments on individuals including their reaction to drugs and vaccines. Said Wang, "some companies are capable of undertaking one or several of the tests, but there is no one like iCarbonX that is able to integrate all of them."

iCarbonX features the following five major infrastructural facilities: Data collection and technical platform, AI data analysis technical platform, smart hardware, data library and sample library. By using such infrastructural facilities, iCarbonX is able to provide office-to-office systems with personalized services to each of its customers.

It is apparent that this is not what a startup can independently achieve. Take for example the establishment of the data library. As Wang put it, there are two main sources for iCarbonX's data. First, it relies on its own technical capability to obtain data such as those on genes, microorganisms, proteins and metabolism. Second, the company depends on its partners for data. These include research institutions, drug makers, testing centers, hospitals, diagnostic companies, insurance companies and health management firms.

Rendering digital life is the objective of iCarbonX. The key to whether it can achieve this target is conditioned on whether it can establish an ecosystem of synergy and collaboration.

04

Chapter 4
Current Situation of Innovation in China

P043-047

Study the current relationship between innovations in the region and find out the possible reasons,
this could significantly enhance China's overall innovation capability.

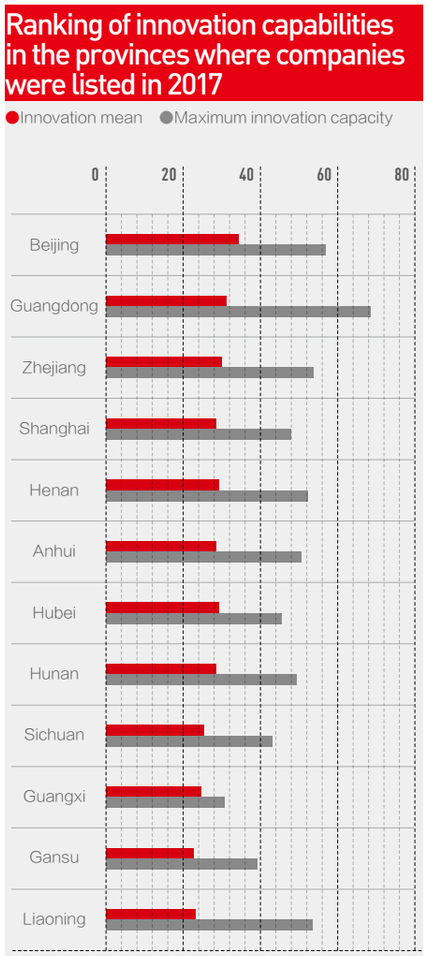
Current Situation of Innovation in China

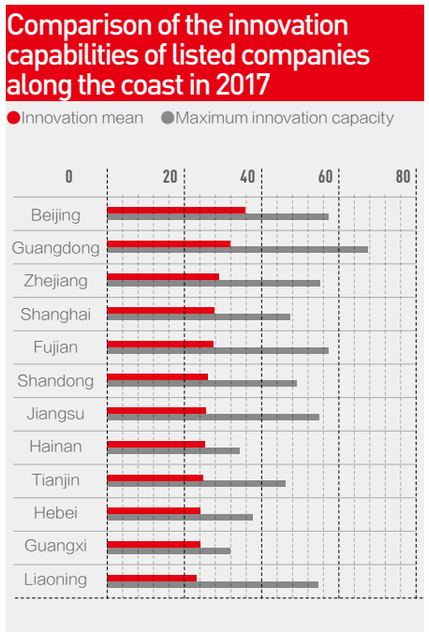
The innovation level of the region is not only based on the performance of local enterprises' innovation ability. The difference of innovation environment in different regions will directly affect the innovation ability of local enterprises, thus establishing a mutual causal relationship. Therefore, we should study the current relationship between innovations in the region and find out the possible reasons. This could significantly enhance China's overall innovation capability.

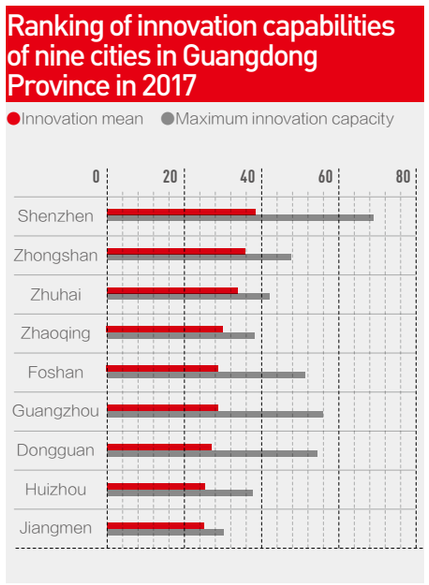
▶ Note:
"Innovation mean" refers to the average score of enterprise innovation in a category (divided by region, industry, etc.), which is calculated by dividing the sum of the enterprise innovation scores of the category by the number of enterprises in the category; the maximum value of innovation is represented by the company with the highest innovation score in this category.

The innovation ability of listed companies generally shows a regional ladder distribution

Looking at the overall distribution of listed companies' innovation levels in China, most innovative companies are located in coastal area, then central, southwest, northwest and northeast areas in that order. The comprehensive innovation level of coastal areas, such as Beijing, Guangdong, and Zhejiang, ranks highest. Central China, such as Henan, Anhui, Hubei, and Hunan, are ranked second. Sichuan, Guangxi, Gansu, Liaoning, and other places come in third. The coastal areas are at the forefront of the country due to their economic development level, and they are rich in innovative infrastructure and resources. These areas are influenced by multinational enterprises. Therefore, the enterprises' level of innovation is higher.







The ranking of innovation ability of listed companies is characterized by differentiation and distribution within the region.

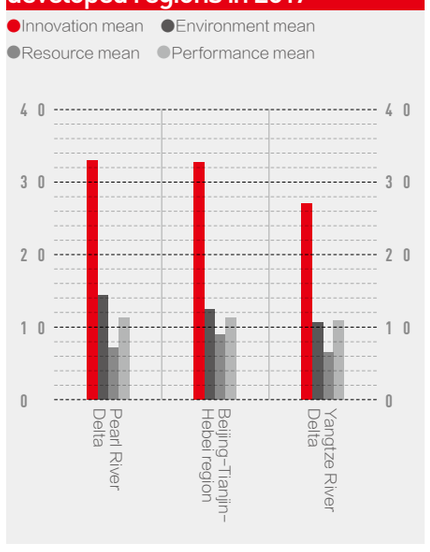
The ranking of listed companies' innovation ability is divided into three levels in different provinces in the coastal areas: The first level is mainly in Guangdong, and the innovation mean is 35.91, which ranks ahead of other provinces in the coastal areas; The second level is Zhejiang, Shanghai, Fujian, and other provinces and cities, and the innovation mean has reached 27 or higher; The third level is Hebei, Guangxi, Liaoning, and other provinces, and the innovation mean is below 25. The level of innovation among listed companies in different cities within the same province is quite varied. Taking Guangdong Province as an example, Shenzhen has the strongest innovation, with a maximum innovation capacity of 67.77 and an innovation mean of 37.79; Jiangmen, Huizhou, and other cities have weaker innovation levels. The maximum innovation capacities of Jiangmen and Huizhou are 37.15 and 29.56, respectively, and the innovation mean is less than 25. There is a big gap between the average scores of innovation and the average scores of listed companies in different provinces and cities in the same region. This reflects the dispersion of the innovation of the provinces and cities and the imbalance of innovation environment and resource allocation.

The Pearl River Delta Economic Zone leads China's innovation capabilities

The Pearl River Delta Economic Zone has the strongest innovation capabilities. In terms of ranking of innovation capabilities, the Pearl River Delta region took the lead with an innovation mean of 33.41; Beijing-Tianjin-Hebei region ranked 2nd with an innovation mean of 33.35; The Yangtze River Delta region ranked third with an innovation mean of 27.69. The Pearl River Delta innovation

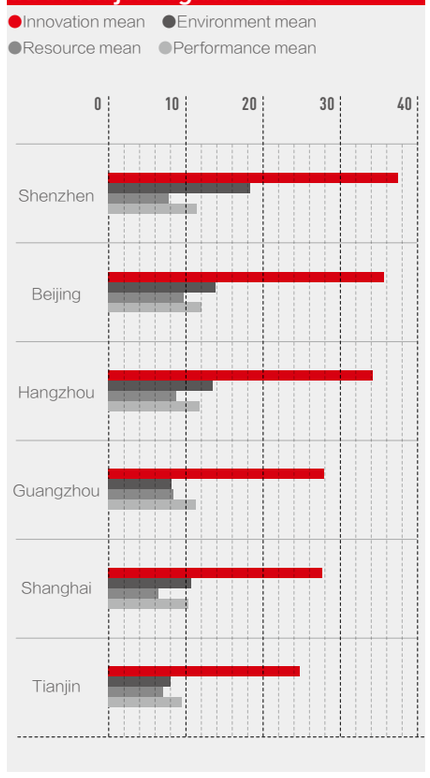
environment ranks first, and the delta region is an environment-driven innovation region; the Beijing-Tianjin-Hebei region ranked first in innovation resources. The region is rich in technical talent and innovative capital; the Pearl River Delta region also ranked first in innovation performance, and the region is home to a number of listed companies with the strongest innovation performance in their respective industries.

Comparison of innovation capabilities in the three major developed regions in 2017



Note: 1. The Pearl River Delta region includes Shenzhen, Zhuhai, Foshan, Guangzhou, Dongguan, Zhaoqing, Jiangmen, Huizhou, and Zhongshan, a total of 9 cities; the Yangtze River Delta region includes Shanghai, Hangzhou, Ningbo, Jiaxing, Shaoxing, and Zhoushan, a total of 6 cities; the Yangtze River Delta includes Shanghai, Suzhou, Wuxi, Changzhou, Zhenjiang, Nanjing, Yangzhou, Taizhou, Nantong, Hangzhou, Ningbo, Jiaxing, Huzhou, Shaoxing, and Zhoushan, a total of 15 cities; the Beijing-Tianjin-Hebei region includes Beijing, Tianjin, Shijiazhuang, Tangshan, Langfang, Handan, Qinhuangdao, Zhangjiakou, Chengde, Baoding, Zhangzhou, Xingtai, and Hengshui, a total of 11 cities.
2. "Environment mean" refers to the average score of the enterprise innovation environment in a certain category (divided by region, industry, etc.). This value is calculated by dividing the sum of the scores of the enterprise's innovation environment in this category by the number of firms in that category; resource mean and performance mean are also calculated in the same way.

Comparison of innovation capabilities of major cities in the three major regions in 2017



Innovation in key cities drives regional innovation

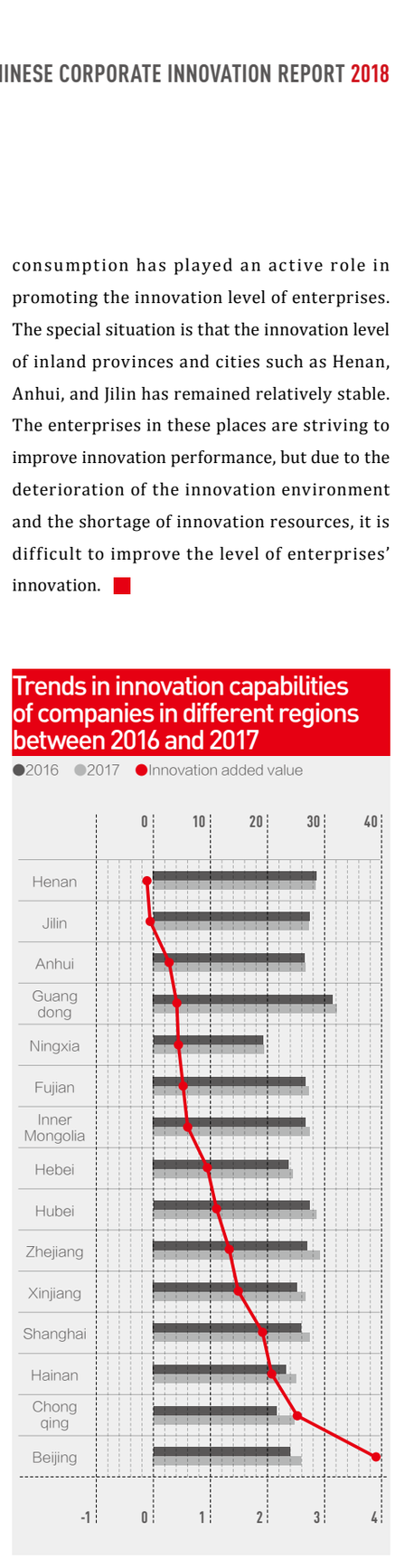
In the city innovation ranking, Shenzhen's innovation mean is 37.79, which is 4.38 higher than the innovation mean of the Pearl River Delta Economic Zone. The superior business environment for innovation and entrepreneurship in Shenzhen drives innovation in the Pearl River Delta region. Beijing's innovation mean is 35.91, which is 2.56 higher than the overall innovation mean in the Beijing-Tianjin-Hebei region. The rich resources of innovation in Beijing's universities, research institutions, and technical talents have driven innovation in the Beijing-Tianjin-Hebei region. Hangzhou's innovation mean is 34.44, which is 6.75 higher than the overall innovation mean in the Yangtze River Delta region. The reason for this is Hangzhou's innovation environment that is superior to its neighboring cities, and the fact that Hangzhou enterprises are more willing to increase investment in innovation.

1. This assessment focuses more on the quality of innovation than on innovative resource agglomeration. Shanghai's innovation resources are more abundant overall, but the city's innovation ability is weak due to poor innovation environment, weak innovation performance, and low level of resources invested by enterprises.

Beijing has led the nation's incremental innovation, but the innovation environment in the central and northeast regions has deteriorated significantly.

If the 2016 and 2017 data are compared, the provinces and cities that have significantly increased their innovation scores are mainly benefited from the improvement of the innovation environment and the improvement of innovation performance. The leader of the first echelon of innovation added value is the Beijing area. In the increasingly unfavorable situation of the international economic situation, Beijing local governments have made efforts to improve the efficiency of government services and expand public services, which is conducive to improving the innovation environment and thereby enhancing the level of enterprises' innovation. The second echelon is Zhejiang, Hubei, Hebei, and other areas. Under the pressure of a major economic downturn, the listed companies in these provinces have firmly embarked on the road of innovation. The promotion of the innovative value of enterprises due to the upgrade of domestic consumption has played an active role in promoting the innovation level of enterprises. The special situation is that the innovation level of inland provinces and cities such as Henan, Anhui, and Jilin has remained relatively stable. The enterprises in these places are striving to improve innovation performance, but due to the deterioration of the innovation environment and the shortage of innovation resources, it is difficult to improve the level of enterprises' innovation. ■

Trends in innovation capabilities of companies in different regions between 2016 and 2017



05

Chapter 5 Guangdong–Hong Kong–Macau Greater Bay Area Enterprise Innovation Environment Analysis

P048-068

The analysis of the enterprise innovation environment in Guangdong–Hong Kong–Macau Greater Bay Area not only has significant meaning for advancing innovation in Guangdong–Hong Kong–Macau Greater Bay Area but also serves as important reference for other city clusters.

Current Situation in Regards to Innovation for Chinese Enterprises

The bay area economy has evolved into an important coastal economy. Based on renowned international bay area case studies, the openness, innovation, internationalization, and other important features of bay areas embody functions for leading innovation and gathering resources. Premier Li Keqiang established plans for developing city clusters in Guangdong-Hong Kong-Macau Greater Bay Area in the Government Work Report on March 5, 2017.

The "9+2" cities in the Guangdong-Hong Kong-Macau Greater Bay Area include Shenzhen, Guangzhou, Dongguan, Zhuhai, Huizhou, Zhongshan, Foshan, Jiangmen, Zhaoqing and the Hong Kong Special Administrative Region (hereinafter referred to as: Hong Kong) and the Macau Special Administrative Region (hereinafter referred to as: Macau). The analysis of the enterprise innovation environment in Guangdong-Hong Kong-Macau Greater Bay Area not only has significant meaning for advancing innovation in Guangdong-Hong Kong-Macau Greater Bay Area but also serves as important reference for other city clusters.

1.

Macro analysis: Guangdong-Hong Kong-Macau Greater Bay Area

Enterprise Innovation Environment Assessment

By constructing an assessment system that includes environmental support, resources capacity, and value of performance, we can conduct a systemic assessment of Guangdong-Hong Kong-Macau Greater Bay Area.

Environmental Support Assessment

Environmental support indicators mainly reflect the external environmental factors, impact of policies and systems, and infrastructure conditions that determine innovation and entrepreneurship.

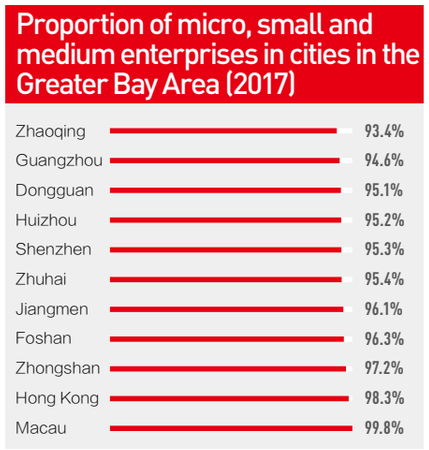
● Active Market Economy and Low Foreign Investment Dependency

Micro, small and medium enterprises are the leading forces for national economic and social development. The number and proportion of urban micro, small and medium enterprises (classified based on number of employees) can generally be used to analyze the activeness of the local market economy. Higher proportions of micro, small and medium enterprises signify a more active market economy.

The proportion of micro, small and medium enterprises in cities in Guangdong-Hong Kong-Macau Greater Bay Area is mostly kept above 90%. The proportion is 99% in Macau and 98% in Hong Kong. Among Mainland cities,

Zhongshan, Foshan, and Jiangmen are the top three with more than 95%. Zhuhai, Shenzhen, and Guangzhou have more high-tech industrial clusters and more large-scale enterprises. Therefore, the proportion of micro, small and medium enterprises is around 95%. Among the 11 cities, only Zhaoqing has a significantly lower proportion of micro, small and medium enterprises (approximately 75%). This is mostly attributed to a higher concentration of heavy industries (accounting for 68.6% [1] of output). It is a city with more prominent traditional industries in the Greater Bay Area.

Proportion of micro, small and medium enterprises in cities in the Greater Bay Area (2017)



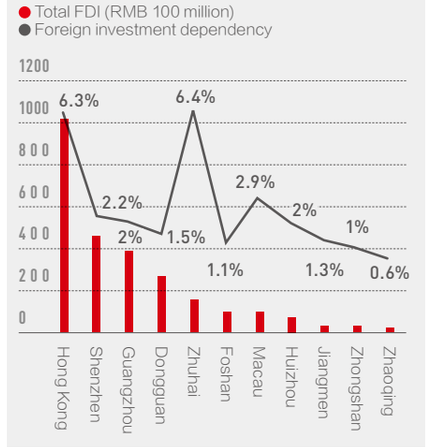
Note: The main sources of data consist mostly of published statistics on the cities from the Third National Economic Census. Statistics of Hong Kong Special Administrative Region are from the Hong Kong Annual Digest of Statistics published by the Government of the Hong Kong Special Administrative Region in 2017. The number of small and medium enterprises in Macau Special Administrative Region in 2016 was not published and data from the White Paperon Micro, Small and Medium Enterprises in Macau 2013 were used.

1: Data from the Zhaoqing Statistical Yearbook 2017.

Foreign direct investment (FDI) is one of the key indicators of modern capital internationalization and it shows the region's attractiveness for foreign investment and economic openness. In terms of the scale of FDI, Hong Kong SAR took first place in the Bay Area with RMB 100.96 billion. It was ranked as the third largest FDI destination in 2017 [2] which demonstrated its position as a global finance center.

Zhuhai's 6.4% foreign investment dependency in 2017 led cities in the Bay Area and surpassed Hong Kong (5.1%) and Macau (3.3%). Other cities in Mainland China had relatively low dependency on foreign investment and only Shenzhen (2.2%), Guangzhou (2.0%), and Huizhou (2.0%) had rates of higher than 2%. The overall foreign investment dependency in the Greater Bay Area is insignificant and it, to a certain extent, wards off negative impact from the decline of globalization trends.

FDI scale and foreign investment dependency in each city (2017)



Note: Data from the statistical bulletins of the cities in 2017. Statistics for Hong Kong SAR were from the 2017 China Statistical Yearbook and statistics for Macau SAR were from the Statistics and Census Service of the Government of Macau Special Administrative Region. FDI refers to foreign direct investment amount used.

2: World Investment Report 2018, United Nations Conference on Trade and Development (UNCTAD)

● Large-Scale Foreign Trade in Hong Kong and Shenzhen and Strong Industrial Foundations in Mainland Cities

Guangdong-Hong Kong-Macau Greater Bay Area includes the most prosperous cities for foreign trade in China. The trading volume exceeded RMB 1 trillion in 3 of the "9+2" cities in the Greater Bay Area in 2017. The cities included Hong Kong (RMB 6596.88 billion), Shenzhen (RMB 2801.15 billion), and Dongguan (RMB 1226.44 billion). Hong Kong contributed to more than half of the import and export in the Bay Area and it is followed by Shenzhen with 21% and Dongguan with 9%.

Proportion of import/export in cities in the Greater Bay Area (2017)

Note: Data from the statistical bulletins of the cities in 2017. Statistics for Hong Kong SAR are from the Census and Statistics Department of Hong Kong Government. Statistics for Macau SAR were 2016 statistics from the 2017 China Statistical Yearbook.

Export trade in Guangdong-Hong Kong-Macau Greater Bay Area exhibit features of a manufacturing industry which benefited from a developed labor-intensive and technology-intensive industry in the Bay Area. Hong Kong's export value of RMB 3105.69 billion in 2017 topped the chart. However, export of products actually produced in Hong Kong remained rare as RMB 3070.87 billion's worth of products were intermediary trade which accounted for close to 98.9% of total exports. The same conditions also apply to Macau (intermediary trade accounted for approximately 80.4% of total exports). Shenzhen's RMB 505.568 billion surplus made it the most competitive city in global trade in Guangdong-Hong Kong-Macau Greater Bay Area. Most cities in Guangdong enjoy trade surpluses of more than RMB 100 billion. This illustrates the prevalence of the historical foreign trade model of "front shop back factory" for Guangdong and Hong Kong.

Total export of the cities (2017)

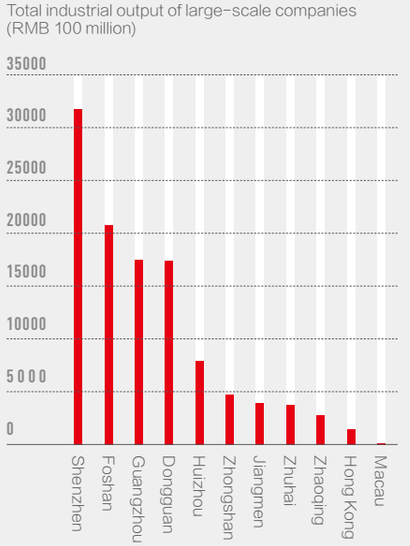
Region	Total value of imports (RMB 100 million)	Total value of exports (RMB 100 million)	Intermediary trade (RMB 100 million)
Hong Kong	34911.89	31056.9	30708.7
Shenzhen	11477.89	16533.57	--
Dongguan	5236.99	7027.38	--
Guangzhou	3922.21	5792.15	--
Foshan	1203.83	3153.6	--
Huizhou	1182.86	2233.13	--
Zhuhai	1107.14	1882.98	--
Zhongshan	525.90	2055.6	--
Jiangmen	309.6	1075.6	--
Macau	631.04	93.87	79.02
Zhaoqing	135.65	222.26	--

Note: Data from the statistical bulletins of the cities in 2017. Statistics for Hong Kong SAR are from the Census and Statistics Department of Hong Kong Government. Statistics for Macau SAR were 2016 statistics from the 2017 China Statistical Yearbook.

Labor-intensive and technology-intensive manufacturers often form clusters that increase the scale of businesses. The industrial output of large-scale companies directly reflects the industrial foundation of the city. Statistics have shown that Shenzhen, Foshan, Guangzhou and

Dongguan have formed industrial clusters with an output of RMB 1 trillion. They are followed by six industrial clusters in Huizhou, Zhongshan, Jiangmen, Zhuhai, Zhaoqing and Hong Kong with an output of more than RMB 100 billion.

Total industrial output of large-scale companies in cities in the Greater Bay Area (2017)



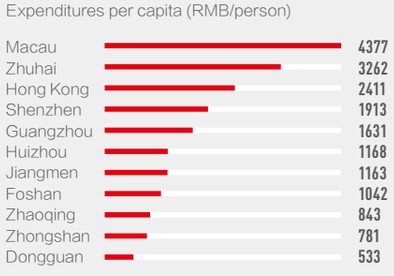
Note: Data from the statistical bulletins of the cities in 2017. Guangzhou statistics are provided up to November 2017 and they are from the Industry and Information Technology Commission of Guangzhou Municipality. Statistics for Macau SAR were 2016 statistics from the 2017 China Statistical Yearbook. Statistics for Hong Kong SAR were not updated to 2017 statistics as of the completion of the draft and statistics from sales and other profits for the manufacturing industry in 2015 were adopted. The statistics were from the Hong Kong Annual Digest of Statistics of 2017.

● Outstanding Social Welfare "West of Zhuhai" and Rich Cultural Resources "East of Zhuhai"

Regions with good social welfare often attract more talents which form the basis for innovation and entrepreneurship. Social security [3] includes healthcare for residents, elderly care, unemployment, housing, and other more comprehensive social security expenditures. It can therefore be used as a basic indicator for measuring social welfare in a region.

Macau SAR had the highest social security expenditures in 2017 with RMB 4,378. In addition to Macau's economic foundations, its "two-tier social security system" (including the Social Security Fund and Central Provident Fund; the former provides basic economic support while the latter distributes bonuses to residents from the government's income) is also a main reason. Zhuhai Special Administrative Region placed second with RMB 3,261 and Hong Kong、Shenzhen and Guangzhou are close behind. Expenditures in other cities were lower than RMB 1,500. The social welfare levels of many Mainland cities did not keep up with economic development and there remains room for significant increases in social security expenditures.

Expenditures per capita for social insurance/security in cities in the Greater Bay Area (2017)



Note: Statistics were from the implementation status of fiscal budgets of the cities in 2017. Statistics for Hong Kong and Macau were from 2016. Statistics for Macau SAR were from the 2017 China Statistical Yearbook and statistics for Hong Kong SAR were from the Hong Kong Annual Digest of Statistics of 2017.

3: "Social insurance" is the term used in Mainland China which corresponds to the term "social security" used in Hong Kong and Macau SARs.

Guangdong-Hong Kong-Macau Greater Bay Area has always been a window for cultural exchanges and integration in China. The spread of science and cultural value is of great importance in the region which retains an excellent sociocultural environment. According to official statistics, the top three cities with the highest number of libraries in the Greater Bay Area in 2017 were Dongguan, Shenzhen and Hong Kong. Cities with the highest number of libraries per capita were Dongguan, Shenzhen, Macau, and Hong Kong while levels in other cities were lower than 0.1 library/10,000 people. If libraries are regarded as a manifestation of sociocultural resources, it can be concluded that the cities in the Greater Bay Area have abundant libraries but unbalanced distribution. This is particularly true for cities with higher proportions of immigrant workers such as Huizhou, Foshan, Guangzhou and Zhuhai. There is a substantial gap between number of libraries per 10,000 people in these cities and cities such as Shenzhen, Hong Kong and Dongguan.

Number of libraries per 10,000 people in the cities in the Greater Bay Area (2017)

Region	Number of libraries	Number of libraries per 10,000 people
Dongguan	653	0.78
Shenzhen	632	0.52
Macau	16	0.25
Hong Kong	82	0.11
Zhongshan	25	0.08
Zhaoqing	9	0.02
Jiangmen	8	0.02
Zhuhai	3	0.02
Guangzhou	14	0.01
Foshan	6	0.01
Huizhou	5	0.01

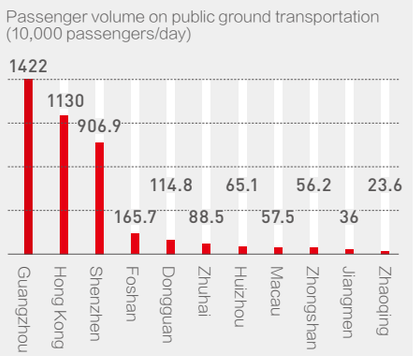
Note: Statistics were from the statistical bulletins of the cities in 2017. Statistics for Macau SAR were from the official website of Macau Public Library and statistics for Hong Kong SAR were 2016 statistics from the Hong Kong Annual Digest of Statistics of 2017.

● Rich Guangdong-Shenzhen-Hong Kong Transportation Resources and Overall Balanced Healthcare Resources

Guangdong-Hong Kong-Macau Greater Bay Area is the bay area with the highest population density in the world. The movement of people inside cities and between cities require efficient transportation systems and the passenger volume of public ground transportation (including buses and rail transportation systems) can be used as an effective indicator for measuring total transportation resources in a city.

The three core cities in the Greater Bay Area — Guangzhou (13.662 million passengers/day), Hong Kong (11.186 million passengers/day), and Shenzhen (8.672 million passengers/day) — topped the rankings in urban public transportation resources in 2016 and contributed to widening gaps with other cities. They are followed by Foshan with 1.756 million passengers/day and Dongguan with 1.16 million/day. Other cities fell short of 1 million passengers/day. The public transportation system in the Greater Bay Area is distributed across three hubs including Hong Kong, Shenzhen and Guangzhou. However, the aforementioned three cities are situated on the east of the Pearl River which is not entirely consistent with the distribution of population in the Greater Bay Area. The urban transportation system in the west of the Bay Area, Dongguan and Huizhou requires additional improvements.

Efficiency of public ground transportation in cities in the Greater Bay Area (2016)



Note: Statistics were from the statistical bulletins of the cities in 2016. Statistics for Macau SAR were from the Transport Bureau of the Macau SAR and statistics for Hong Kong SAR were from the Hong Kong Annual Digest of Statistics of 2017.

Healthcare resources are an important foundation for socioeconomic development. Protecting innovation and entrepreneurship for production, learning, and research for stable and continuous investment and the overall quantities of hospitals and healthcare institutions are the basic signs for medical technology capacity and the level of healthcare services. Mainland cities achieved high rankings in terms of the total quantities of healthcare institutions. With regard to the number of general hospitals in 2017, Guangzhou's 243 hospitals placed it on top of the list and it has become an area with a high concentration of medical resources in Guangdong. Zhaoqing, Shenzhen and Foshan also have more than one hundred general hospitals. In terms of the number of general hospitals as a proportion of medical institutions, Hong Kong SAR's 30.7% placed it first while levels in other cities were kept at around 5%. This reflects the structure of Hong Kong's advanced healthcare system and leading healthcare services.

Number of healthcare resources in the cities in the Greater Bay Area (2017)

Region	Number of general hospitals	Number of healthcare institutions	Ratio of general hospitals among healthcare institutions
Guangzhou	243	3126	7.8%
Zhaoqing	148	3079	4.8%
Shenzhen	135	3492	3.9%
Foshan	110	1715	6.4%
Dongguan	89	2047	4.3%
Huizhou	70	2668	2.6%
Zhongshan	59	806	7.3%
Hong Kong	42	140	30%
Zhuhai	43	742	5.8%
Jiangmen	44	1608	2.7%
Macau	15	689	2.2%

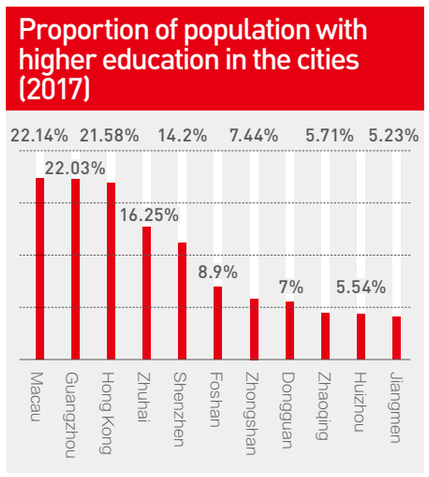
Note: Data from the statistical bulletins of the cities in 2017. With regard to the definitions of "general hospitals", they are defined in Macau SAR as "hospital/daytime hospitals and sanitation centers". The statistics are from the Statistics and Census Service of the Government of Macau SAR. They are defined in Hong Kong SAR as "hospitals under the jurisdiction of the Hospital Authority". Statistics were from the Health Facts of Hong Kong 2018 Edition which was published by the Department of Health.

Resources Capacity Analysis

● Guangzhou retains high levels of highly educated talents while Shenzhen, Hongkong and Macau Leads the Knowledge Economy.

Guangdong-Hong Kong-Macau Greater Bay Area is an area with numerous education resources for higher learning. Hong Kong, Macau, Guangzhou, Zhuhai and other cities have numerous institutions for higher learning, which is indirectly reflected in the proportion of population with higher education . Macau had the highest proportion of the population with higher education with 22.14% in 2017. It is followed closely by Guangzhou and Hong Kong. Zhuhai also surpassed 15%. Shenzhen may have fewer higher education resources but its industrial development absorbed many talents with higher education and its ratio is approaching 15%. Less than 10% of the population in other cities have higher education [4]. This type of distribution is affected by higher education resources and exemplified in the demand for higher education talents in the local industrial structure. With regard to the current state of industries in the Greater Bay Area, it is exemplified in the high-tech manufacturing and advanced manufacturing services sectors.

Proportion of population with higher education in the cities (2017)

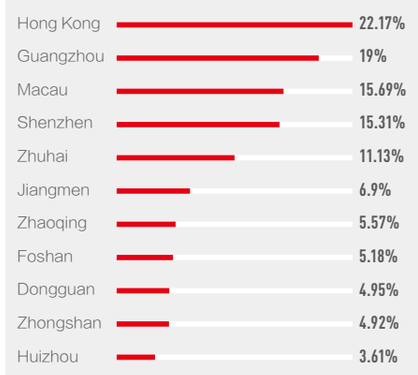


Note: The statistics mainly derived from the Sixth National Population Census in the cities in 2010. Statistics for Hong Kong SAR were from the Hong Kong Annual Digest of Statistics of 2017. Statistics for Macau SAR were from the 2017 China Statistical Yearbook. Both were 2016 statistics.

4: The ratio of population with higher education in Mainland cities were from the Sixth National Population Census in 2010. Statistics from Hong Kong and Macau SARs were from 2016.

Knowledge-intensive service industries directly provide professional services to final consumers and businesses that conduct innovative activities. They play the roles of the promoter, conduit, and initiators in the innovative process and they are important infrastructure for innovation. The proportion of people engaged in knowledge-intensive services in Guangdong-Hong Kong-Macau Greater Bay Area is relatively low with 22.9% in Hong Kong which ranked the highest in the Bay Area and was also the only city with more than 20%. Macau and Shenzhen took second and third place while levels in cities like Guangzhou and Zhuhai were lower than 10%. This shows that the main cities in the Greater Bay Area had relatively weaker resources capacity for advancing innovation and lower penetration of knowledge innovation in the service sector. From the perspective of the industry, a city with ideal structural deployment, such as Shenzhen, promotes the synergistic development of high-tech manufacturing and knowledge-intensive services. On the contrary, excessive reliance on low-grade manufacturing and lack of industrial upgrade would, to a certain extent, hinder the development of services toward high-end and innovative businesses. Examples include Jiangmen, Huizhou and Zhongshan.

Proportion of people working in knowledge-intensive services in cities in the Greater Bay Area (2016)



Note: Statistics were from the statistical yearbooks of the cities in 2017. Statistics for Macau SAR were from the 2017 China Statistical Yearbook and statistics for Hong Kong SAR were from the Hong Kong Annual Digest of Statistics of 2017.

Total market value of listed companies in cities in the Greater Bay Area (2017)

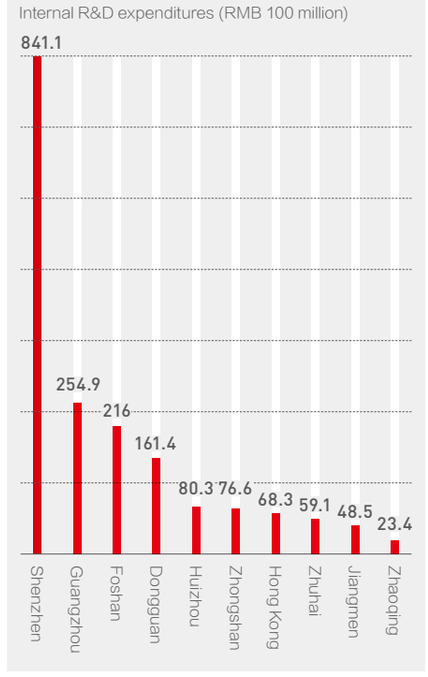
Region	Total market value of listed companies (RMB 100 million)	Total market value distribution
Hong Kong	272426.57	72%
Shenzhen	65822.61	17.4%
Guangzhou	16131.35	4.3%
Foshan	7758.52	2.1%
Zhuhai	5056.60	1.3%
Macau	4419.65	1.2%
Zhongshan	2155.18	0.6%
Dongguan	2052.89	0.5%
Huizhou	1364.11	0.4%
Jiangmen	537.60	0.1%
Zhaoqing	448.21	0.1%

Note: The data came from the financial terminal of Wind Information.

● Hong Kong Continues to Develop Capital Market and Shenzhen Leads in R&D Investments

The main bodies for innovation in Guangdong-Hong Kong-Macau Greater Bay Area are mainly companies. The market value and performance of listed companies are directly related to the company's innovation and investment. Therefore, the total market value of listed companies in each city can, to a certain extent, reflect the intensity of capital investment for innovation. The total market value of companies listed on the Hong Kong Exchange in 2017 amounted to RMB 27242.66 billion which totaled 72% of the market value of all listed companies in the Greater Bay Area. Hong Kong's position as the financial center of Asia provides it with overwhelming advantages in the internationalization and maturity of the securities market. With so many outstanding companies on the Hong Kong Exchange, such a high total market value was no accident. Shenzhen leverages large numbers of high-tech manufacturing companies and technology companies to take second place. Guangzhou is placed in third while the market value of listed companies in other cities did not exceed 4%. These statistics largely reflect the activeness of companies in the capital market and the congregation of capital for innovation based on the core areas of Hong Kong, Shenzhen and Guangzhou.

R&D expenditures of large-scale industries in cities in the Greater Bay Area (2017)



Note: Statistics were from the statistical yearbooks of the cities in 2017. Statistics for Hong Kong SAR were from the Hong Kong Annual Digest of Statistics of 2017. There was a bigger gap in the R&D investment of large-scale industries in Macau SAR and that of other cities and it is therefore not shown in the figure.

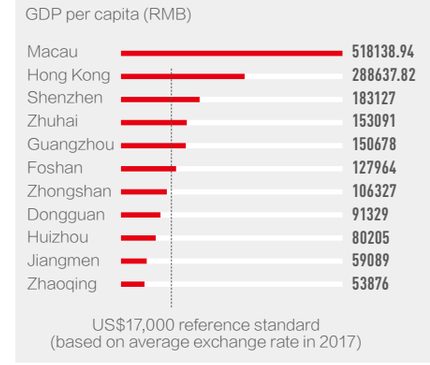
The proportion of research and development (R&D) investment in the GDP is a universal indicator used to assess regional investment in science and technological research and development and technological competitiveness. The intensity of R&D investment in main cities in the Greater Bay Area and the distribution of the manufacturing industry, particularly the high-tech manufacturing industry, are highly correlated. Shenzhen's internal R&D expenditures reached RMB 76 billion in 2016 which led the Greater Bay Area. Cities with more than RMB 10 billion in R&D investment in the same year included Guangzhou, Foshan and Dongguan. However, the sum of the three cities still fell short of R&D investments in Shenzhen.

Performance Value Assessment

● Outstanding Performance of Hong Kong and Macau and High-End Exports from Shenzhen

According to the Global Competitiveness Report published by the World Economic Forum, one of the indicators for the phases of regional development is a GDP per capita of US$17,000 which means that development in the region is advancing toward the stage of innovation-driven development. Six cities in Guangdong-Hong Kong-Macau Greater Bay Area had a GDP per capita of over US$17,000 which means that the main economy in the Greater Bay Area has entered the stage of innovation-driven development. The city in the Greater Bay Area with the highest GDP per capita in 2017 was Macau SAR with RMB 518,000 (US$77,000). It is among one of the most prosperous regions in the world. Macau's economy has improved significantly since its transfer of sovereignty and it is a region that enjoys the most development bonus for high-speed domestic economic development. Hong Kong took second place with a GDP per capita of RMB 289,000. Levels in Mainland cities did not reach RMB 200,000 in the current year. Per capita GDP was RMB 183,000/person in Shenzhen, RMB 153,000/person in Zhuhai, RMB 151,000/person in Guangzhou, RMB 128,000/person in Foshan, and RMB 106,000/person in Zhongshan. GDP per capital in other cities were lower than RMB 100,000.

Per-capital GDP of respective cities in the Greater Bay Area (2017)

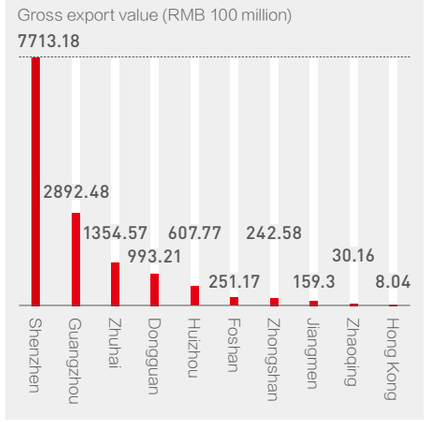


Note: The data came from statistical communiques of 2017 of respective cities. Data of the Hong Kong and Macau Special Administrative Regions came from the Census and Statistics Department of Hong Kong and the Direcção dos Serviços de Estatística e Censos (DSEC) of Macau.

As shown by speedy development of the high-tech industry, the industrial structure is growing towards the knowledge-based technical medium-to-high end and also reflects to a certain extent the active state of innovation and entrepreneurship. The high-tech industry in Guangdong-Hong Kong-Macao Greater Bay Area is obviously foreign trade export-oriented. The export of related products can reflect the economic benefits for the industry brought about by innovative development. The gross export value of high-tech products in Shenzhen reached RMB 771.32 billion in 2017, accounting for 46.7% of the overall export value of the city and

taking the lead throughout the whole Greater Bay Area. The runner-ups were Guangzhou, Zhuhai and Dongguan, whose export value, was also respectively close to or exceeding RMB 100 billion. The difference from that of Shenzhen, however, still remains significant.

Gross export value of high-tech products of respective cities in the Greater Bay Area (2017)

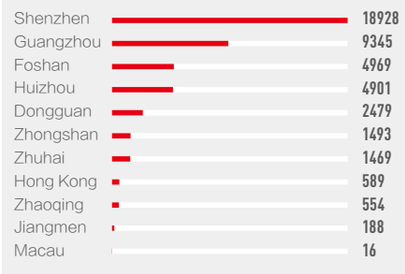


Note: The data came from statistical communiques of 2017 of respective cities. Data of the Hong Kong Special Administrative Region came from the website of the Census and Statistics Department of Hong Kong. Due to the fact that the expors of high-tech products of Macau Special Administrative Region differs relatively greatly from that of other cities, they are not shown in the figure.

● Guangzhou and Shenzhen are active in innovation while Zhuhai and Foshan arepreparing for breakthroughs

Guangdong-Hong Kong-Macao Greater Bay Area has the core group of cities with the most concentrated contributions to the intellectual property rights of Guangdong Province. Authorization of invention patents is the best common indicator of innovation, directly reflecting the innovative power of cities in the Greater Bay Area. Throughout 2017, up to 8928 invention patents were authorized in Shenzhen because it is one of the most active cities in terms of innovations in China , while having further added to its difference from other cities in the Greater Bay Area . Guangzhou had 9345 patents authorized, coming the second. Foshan, Huizhou, Dongguan, Zhongshan and Zhuhai, on the other hand, obviously lagged behind . The number of invention patents authorized in the same year of other cities did not exceed 1,000, respectively. With Shenzhen at its heart, the distribution pattern of high-quality intellectual property rights that Guangzhou and Dongguan represent answers to the accurate positioning of Guangzhou Shenzhen scientific and technological innovation corridor. At the same time, it shows that two innovation-oriented industrial belts, one along the eastern bank of the Pearl River represented by Shenzhen and Guangzhou and the other one on the western bank of the Pearl River represented by Zhuhai and Foshan, are taking initial shape inside the Greater Bay Area. The spear-heading and leading effects demonstrated by the above-mentioned cities should be proactively maximized to lay a desirable foundation of intellectual property rights for the innovative development in the Greater Bay Area.

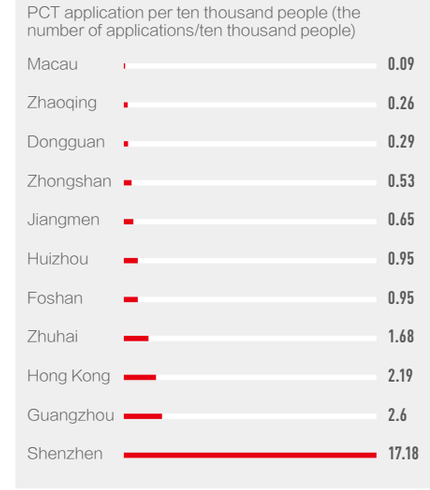
The number of domestic invention patents authorized in respective cities of the Greater Bay Area (2017)



Note: The data came from the 2017 Guangdong Patent Statistics, Intellectual Property Database of Guangdong. The data of Hong Kong and Macau Special Administrative Regions came from the 2017 Statistical Report of State Intellectual Property Office of the People's Republic of China , State Intellectual Property Office of the People's Republic of China.

According to the criteria universally adopted by various countries, the number of PCT patents applied for per ten thousand people is an ideal measurement of the international patent density. Throughout 2017, 20457 PCT patents were applied for in Shenzhen, accounting for more than 75% of those in the Bay Area; the number of PCT patents applied for per ten thousand people was up to 17.18, reflecting the capability of Shenzhen in terms of independent innovation. Guangzhou came the second with 2441 PCT patents applied for and Dongguan the third with 1829. None of other cities had more than 1,000 PCT patents applied for in the same year. As far as the per-capita level is concerned, except for Shenzhen, Guangzhou, Hong Kong and Zhuhai, the number of PCT patents applied for per ten thousand people in other cities was also below 1 per ten thousand people. The indicator performance of Hong Kong and Macau was relatively low as well. The PCT application status in respective cities proves the characteristic primary and secondary distributions of technological innovation performance on the eastern and western banks of the Pearl River on the one hand and reflects the fact that the awareness of active and proactive promotion of internationalization of intellectual property rights is not enough in most cities on the other hand.

The of PCT patents applied for per ten thousand people in respective cities of the Greater Bay Area (2017)



Note: The data came from the 2017 Guangdong Patent Statistics, Intellectual Property Database of Guangdong. The data of Hong Kong and Macau Special Administrative Regions were that of 2016 and came from 2016 Statistical Report of State Intellectual Property Office of the People's Republic of China , State Intellectual Property Office of the People's Republic of China.

Overall Assessments and Enlightenments

Guangdong-Hong Kong-Macao Greater Bay Area is known for its advantageous location and has long been the source of innovation and the trial field for reforms in terms of the system, economy, industry and technology over a long term. After nearly 40 years of development since reform and opening-up, the Greater Bay Area has evolved from being an export-oriented OEM processing site that relied on cheap production factors to the gateway to an open new economy. With the establishment of (Guangdong) Pilot Free Trade Zone of China and the promotion of the " Belt and Road Initiative", the innovative environment of Guangdong-Hong Kong-Macao is being further optimized. Innovation capabilities continue

to build up and the innovative output levels are being constantly enhanced, showing a trend to continuously catch up with the world's Top 3 bay area economies.

In order to more comprehensively and precisely evaluate, compare and contrast the innovative development of respective "9+2" cities in Guangdong-Hong Kong-Macao Greater Bay Area, on the basis of standardized processing of the source data for respective indicators of cities in the Greater Bay Area, the 11 cities are measured and rated for their creativity through standardization and equalization and the ratings are used accordingly to compare the relative levels of these 11 cities in innovative development. The findings are provided below:

● As a whole, the Greater Bay Area forms "four centers" for innovation.

As far as the overall creativity rankings of cities in the Greater Bay Area are concerned, Shenzhen has scored 89.83 (out of 100) , ranking the first, closely followed by Hong Kong with a score of 85.13 and then Guangzhou with a score of 73.49. Cities performing fairly include Macau (59.68), Zhuhai (58.04), Dongguan (53.85), and Foshan (52.24).

As shown by scores, the innovative "four-center" pattern is taking shape. The overall capabilities of Shenzhen in terms of innovation have exceeded those of Hong Kong and the score of Guangzhou is quite close to that of Hong Kong, too. Zhuhai and Foshan also appear to be catching up with Macau. For nearly half a century, the imbalanced economic development in Guangdong, Hong Kong and Macao is being gradually replaced by the innovative progress made by these cities. Cities in Guangdong have begun to take up a more important geographically strategic role.

Creativity index scores and rankings of cities in the Greater Bay Area (2017)

Cities	Creativity index scores	Rankings
Shenzhen	87.88	1
Hong Kong	81.77	2
Guangzhou	73.22	3
Macau	59.54	4
Zhuhai	56.59	5
Dongguan	50.63	6
Foshan	49.97	7
Zhongshan	44.59	8
Huizhou	42.65	9
Jiangmen	38.27	10
Zhaoqing	35.77	11

● Guangzhou-Shenzhen-Hong Kong is the most mature group of cities in the innovative settings of the Greater Bay Area.

When viewed from the itemized indicator of environmental support and ranking, Hong Kong ranks the first , leading by a certain margin compared with the second place Shenzhen and the third place Guangzhou. The accomplishments achieved by Hong Kong are mainly attributed to its exclusive advantages as the international center of finance, which is particularly demonstrated in its huge FDI scale and the gross import and export value . Even if the macro-economic aspects are not considered, Hong Kong also stands out impressively in terms of its systematic urban construction . The highly efficient public transportation system, the highly penetrating mobile Internet, and the extensively distributed general hospitals, among others, are the high-quality social environment of Hong Kong in a nutshell. For nearly 40 years since reform and opening-up, the far-reaching progress accomplished by inland cities represented by Shenzhen and Guangzhou has changed the economic landscape of the Greater Bay A rea over a long term. In the future, the experiences of Hong Kong in developing its systems, culture, and related services are even more wroth learning in order to create an environmental aura more conducive to innovative development .

Environmental support scores and rankings of cities in the Greater Bay Area (2017)

Cities	Scores of environmental support	Rankings
Hong Kong	38.88	1
Shenzhen	34.6	2
Guangzhou	29.87	3
Zhuhai	25.02	4
Dongguan	23.79	5
Macau	22.79	6
Foshan	22.77	7
Zhongshan	20.13	8
Huizhou	19.7	9
Jiangmen	16.46	10
Zhaoqing	14.62	11

● The "Two Corridors of the Pearl River" is the place where the innovative resource is the most concentrated in the Greater Bay Area.

"Guangzhou-Shenzhen-Hong Kong Scientific and Technological Innovation Corridor" and its surroundings ranks one of the first three As in the sub-item of innovative resources. Thanks to the advanced financial market and a perfect capital operation system, Hong Kong is absolutely taking the lead in the investment of innovative capital. In addition, Hong Kong has three of the Top 10 universities in Asia and is highly competitive in the cultivation of high-end talents. Shenzhen, on the other hand, has relatively insufficient resources to support innovation. The supply of innovative talents, in particular, is in shortage. Nevertheless, Shenzhen is the city with the most successfully adjusted industrial structure in the Greater Bay Area. Talents are powerfully enrolled thanks to the re-distribution of resources. In addition, Shenzhen highly emphasizes technological innovation and its technological finance and R&D budget always top the national list. The demand for allocation of resources by new economy has shaped Shenzhen into the convergence center of innovative resources in the Greater Bay Area. Guangzhou owns relatively powerful reserve of innovative resources. Its industrial structure, however, is transforming relatively slowly. Liquid innovative resources often tend to flow toward areas with stronger demands for innovation. Therefore, Guangzhou takes up more of the role of talents and technological outcome export with its comprehensive supply of creativity.

"Foshan-Zhongshan-Zhuhai-Macau Innovation Corridor" on the western bank of the Pearl River, has the most potential reserve of innovative resources. Cities in this area have their own advantages in terms of resources, such as the diversified culture and exhibition industry in Macau, the leisure and tourism industry in Zhuhai, the home appliance manufacturing industry in Zhongshan and the electronics manufacturing industry in Foshan. All of these unique industrial resources are still pending further enhancement in order to create a modernsystem of high value-added service sectors . The western bank of the Pearl River, making the best of the location

and advantageous transportation of Zhuhai as the core city,, reinforces its collaboration with cities along "Guangzhou-Shenzhen-Hong Kong Scientific and Technological Innovation Corridor" in innovation and also the liquidity and introduction of innovative elements to form an alternating, division of labor and collaborative development layout with the eastern bank of the Pearl River.

Resources capability scores and rankings of cities in the Greater Bay Area (2017)

Cities	Scores of resource capability	Rankings
Hong Kong	30.3	1
Guangzhou	29.15	2
Shenzhen	28.38	3
Macau	22.16	4
Zhuhai	18.99	5
Foshan	14.92	6
Zhongshan	13.32	7
Dongguan	13.01	8
Jiangmen	11.48	9
Huizhou	11.31	10
Zhaoqing	11.11	11

● Shenzhen is the "core engine" of technology and innovation performance in the Greater Bay Area.

When viewed from the itemized indicator of innovation performance and rankings, Shenzhen is unparalleled with its score that is nearly twice that of any other city. Meanwhile, the outstanding performance in the sub-item of innovation performance has also spurred up Shenzhen to become the city with the most powerful comprehensive creativity in the Greater Bay Area. The privileged innovation performance of Shenzhen is attributed to its clustered high-tech manufacturing sectors of a large scale. The industrial development featuring the spear-heading information industry oriented for smart manufacturing enables Shenzhen to stand out in the fields of international and domestic intellectual property rights and contribute to impressive innovation outcome. Meanwhile, it has promoted the speedy development of related industries in the peripheral cities, such as Dongguan and Huizhou.

Innovation performance scores and rankings of cities in the Greater Bay Area (2017)

Cities	Performance-value score	Rankings
Shenzhen	24.9	1
Macau	14.59	2
Guangzhou	14.2	3
Dongguan	13.82	4
Hong Kong	12.59	5
Zhuhai	12.59	6
Foshan	12.27	7
Huizhou	11.63	8
Zhongshan	11.13	9
Jiangmen	10.34	10
Zhaoqing	10.05	11

2.

Midscopic: Construction of Innovation Network among Enterprises in Cities of Guangdong-Hong Kong-Macao Greater Bay Area

While investments in innovation constantly expand in respective cities of Guangdong-Hong Kong-Macao Greater Bay Area, building up a highly-efficient innovation network will be crucial to enhance the utilization rate of innovative resources and advancement of synchronized innovation among respective cities. The intercity innovation network is taking shape mainly thanks to the collaboration of organizations such as enterprises, universities and scientific research units in research and development. The most important performance is the joint application for patents. Invention patents, in particular, can best depict the number of joint applications in innovation as an ideal indicator of inter-city collaboration in innovation.

Innovation Network is taking shape yet requires reinforcement; Guangzhou and Shenzhen become hubs of the Network.

A key to the construction of the innovation network in Guangdong-Hong Kong-Macao Greater Bay Area lies in the reasonable allocation of the flows of innovative resources among the cities. Shenzhen and Guangzhou, as the cities with the most abundant innovative resources as a whole, are responsible for leading other cities in collaborative innovation. The status of invention patents jointly applied for among the cities in Guangdong-Hong Kong-Macao Greater Bay Area of 2017 obviously shows that Shenzhen and Guangzhou have exercised important pivotal effects. The five groups of cities with the biggest number of invention patents jointly applied for all have to do with

The number of invention patents jointly applied for in respective cities of the Greater Bay Area (2017)

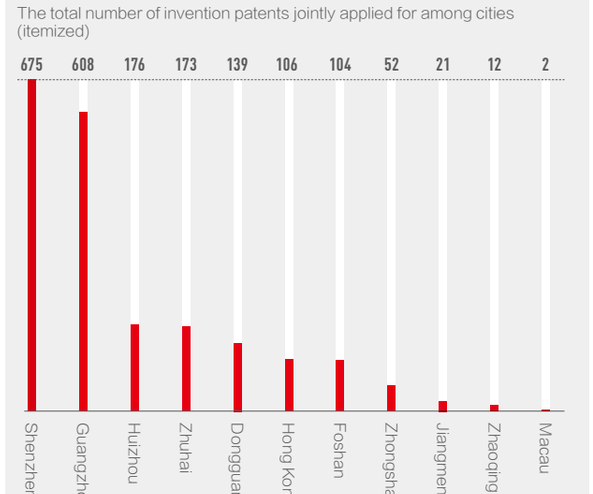
Note: The data came from the State Intellectual Property Office of the People's Republic of China.

Shenzhen and Guangzhou. The group with the closest collaboration in innovation consisits of exactly Shenzhen and Guangzhou. They have jointly applied for 292 invention patents. The initial scale of the innovation network in Guangdong-Hong Kong-Macao Greater Bay Area centering Shenzhen and Guangzhou is taking shape. From Shenzhen, the scope has reached out to adjacent cities such as Huizhou and Dongguan and from Guangzhou, the scope has reached out to Zhuhai and Foshan.

Throughout 2017, the number of invention patents applied for in Guangzhou and Shenzhen was 36941 and 60258, respectively. Their ratio in the joint applications of the Greater Bay Area was only 1.64% and 1.12%, indicating that the innovation activities in the Greater Bay Area were during the intra-city operation stage. Hong Kong and Macau, due to their system differences, are unable to work closely with the inland cities in innovation. Other cities, on the other hand, were unable to be integrated in the overall innovation network due to their inferior innovative resources.

This is why it is hard to build up a innovation network in Guangdong-Hong Kong-Macao Greater Bay Area overnight. Hong Kong, Shenzhen and Guangzhou need to open up innovative resources to other cities while other cities need to take full advantage of their local unique resources to be comparable to Hong Kong, Shenzhen and Guangzhou in order to find a matching point in collaborative innovation and to expedite transformation of technological accomplishments and enhancement of technological innovation capabilities. As for the integration of innovative resources available in respective cities, attention should not be excessively focused on the economic benefits for a single city; the Greater Bay Area should be taken into consideration as a whole with innovative resources allocated to form a highly-efficient innovation network.

The total number of invention patents jointly applied for in respective cities of the Greater Bay Area (2017)

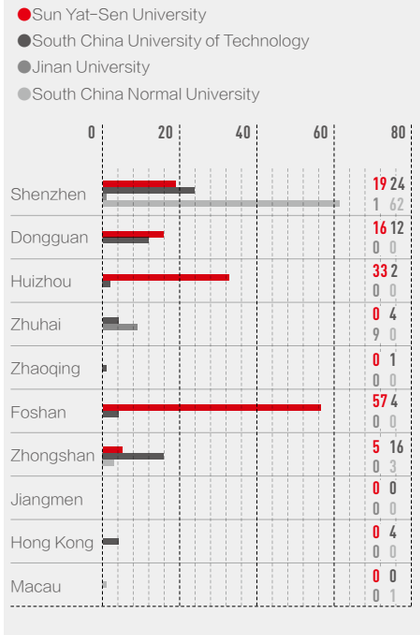


Note: The data came from the State Intellectual Property Office of the People's Republic of China.

Universities spur up Urban Innovation and Play a Crucial Role in Collaboration

As the main entity in joint applications, universities and colleges in Guangzhou play a very important role. Guangzhou is known for its best-quality educational resources for advanced studies in Guangdong Province. Most of the innovation talents are cultivated by universities. Sun Yat-Sen University, South China University of Technology, Jinan University, and South China Normal University, these four universities in the original 985 and 211 projects are particularly important in this regard. Among 864 invention patents jointly applied for in the Greater Bay Area, 40% have to do with these four universities in Guangzhou, directly reflecting the importance of innovative resources of universities in the construction of an innovation network. Creating a partnership in innovation between respective cities and universities is an important link in the construction of an innovation network in Guangdong-Hong Kong-Macao Greater Bay Area.

Number of invention patents jointly applied for in respective cities of the greater bay area (2017)



Note: The data came from the State Intellectual Property Office of the People's Republic of China.

Universities in Guangzhou are equipped with the basis to work with respective cities in innovation. Respective cities should proactively create a desirable partnership with universities and they should jointly set up related scientific research institutions. These four universities have shown obvious locality differences in their collaboration with other cities in innovation. The collaboration in innovation between Sun Yat-Sen University and Foshan is the closest. Meanwhile, collaboration in innovation to a certain extent also exists with Shenzhen and Huizhou. South China University of Technology is the primary collaborative univeristy of cities such as Dongguan and Zhongshan in innovation. Zhuhai mainly works with Jinan University in innovation. Collaboration of South China Normal University in innovation basically focuses in Shenzhen.

Many domestic well-known universities have followed one another to settle down in Shenzhen. In the future, Shenzhen will become another city in Guangdong that gathers high-quality educational resources for advanced studies after Guangzhou. Respectively cities should have their specific directions and proposals defined early on in order to begin collaboration with such universities and to realize effective utilization and collaborative development of innovative resources as soon as possible. Hong Kong, the home to many world-famous universities, is known for its extremely strong capabilities in scientific research and innovation. Due to its industrial positioning and its system difference from inland cities, however, scientific research outcome is unable to be effectively transformed and optimal interaction with inland cities has been unable to begin. Therefore , respective cities should hold onto the opportunities brought about by the preparation and release of the development master plan for Guangdong-Hong Kong-Macao Greater Bay Area to proactively set up a sustainable partnership in innovation with respective universities in Hong Kong and let their own advantageous industry become the transforming platform for the innovation outcome.

3.

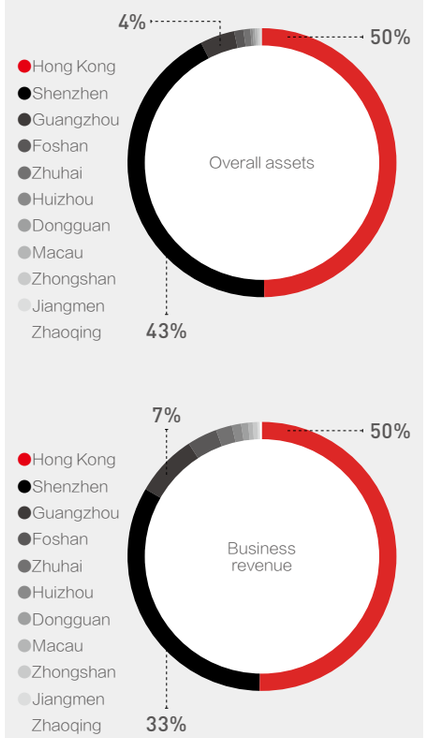
Micro-scopics: Performance in Innovation of Listed Companies in Guangdong-Hong Kong -Macao Greater Bay Area

The innovation network of Guangdong-Hong Kong-Macao Greater Bay Area is under construction. Enterprises, particularly listed companies, are the primary entities of the innovation. Listed companies will release data such as research and development staff, invention patents and other innovative resources. The ratio of research and development expenditure in the revenue can serve as the intensity indicator of research and development to reflect the innovation status of listed companies.

Highly Concentrated Capital of Listed Companies and Innovation Network Created Radiantly from the Corridor

Capital is the foundation of innovation. Hong Kong, Shenzhen and Guangzhou account for 97% of the overall capital of listed companies in the Greater Bay Area. The highly concentrated capital market results in the imbalance of innovation activities in the Greater Bay Area. As such, the innovation network to be built in the Greater Bay Area has to radiate from the core hubs of Guangzhou-Shenzhen-Hong Kong corridor to make it impossible to realize synchronized and balanced development of respective cities. The structure of contributions of listed companies in respective cities to the economy, by the same token, reflects consistent results of the overall assets. Hong Kong, Shenzhen and Guangzhou account for up to 90%.

The structure of capital markets in respective cities of the Greater Bay Area (2017)



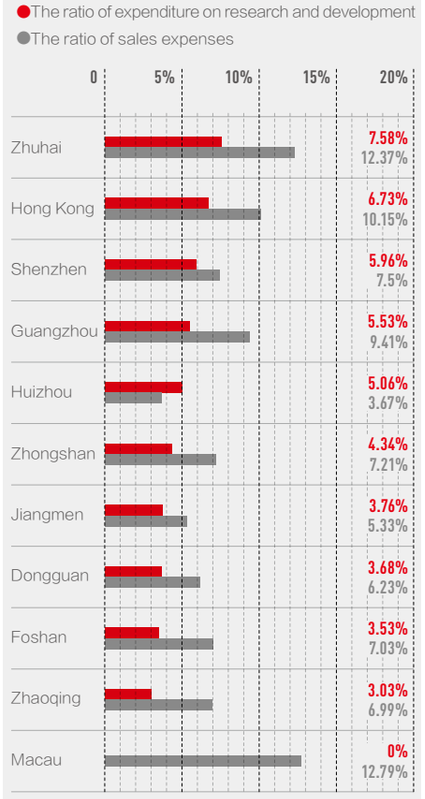
Note: The data came from the financial terminal of Wind Information.

Enterprises of mainland China Emphasize Investment in Innovation as well as Reinforced Research and Development to Reinforce Price Negotiation Ability.

In Guangdong-Hong Kong-Macao Greater Bay Area, the research and development intensity of listed companies in Zhuhai, Hong Kong, Shenzhen and Guangzhou is obviously higher than that of other cities. This has to do with the energetic devotion to the development of new technologies and the advanced manufacturing sector in these cities; it is also closely related to the emphasis placed on innovation in the cities where listed companies are based.

Macau, with a relatively big ratio of listed companies in the service sector, seldom needs to reinforce its competitiveness through research and development. The overall research and development intensity of its listed companies fails to reach the average level in the Greater Bay Area. Enterprises in Macau also have an obviously higher ratio of expenditure on advertising and promotion.

Innovation and sales behaviors of listed companies in respective cities of the Greater Bay Area (2017)

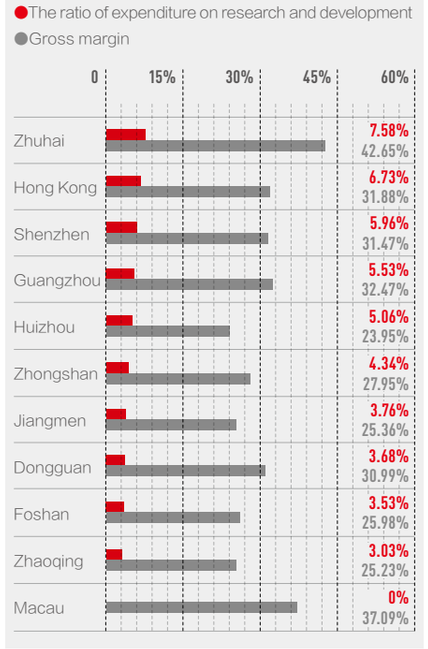


Note: The data came from the financial terminal of Wind Information.

This also has to do with the fact that the service sector accounts for the major portion.. Sales expenses and expenditure on research and development, both as a type of the overhead, can improve the competitiveness of an enterprise and exercise alternative effects in a sense . Other cities, unlike Macau, pay more attention to investments in innovation. Due to the fact that listed companies in developed regions are larger in capital size and are more capable in terms of capital to devote themselves to non-fundamental production activities, Hong Kong, Shenzhen and Guangzhou demonstrate more powerful market competitive advantages in terms of research and development and sales.

For listed companies, although the increase in the research and development expenditure holds back advertising and promotion for the short term, while higher-quality products are brought about, the price negotiation ability of enterprises is enhanced at the same time . In Zhuhai, the city with the highest R&D intensity in Guangdong-Hong Kong-Macao Greater Bay Area, enterprises have the highest gross margin. Hong Kong, Shenzhen and Guangzhou that closely follow also have a gross margin of more than 31%. Among other seven cities, only Macau is above this level. The pricing behavior of enterprises has to do with their innovation activities to a significant extent. Listed companies with increased expenditure on research and development can enhance the competitive advantages of their products to a certain extent, hence accordingly enhancing the premiums of their products and creating even bigger room for product-pricing.

Innovation and pricing behavior of listed companies in respective cities the Greater Bay Area (2017)



Note: The data came from the financial terminal of Wind Information.

Reinforced Enterprise R&D Intensity and Enhanced Overall Market Performance

Besides the capital market structure and the overall behavior of listed companies in the market in respective cities, the utility of innovation activities will eventually be reflected in corporate performance. In the measurement of corporate performance, usually the return on total assets (ROA) and the rate of return on net assets (ROE) are adopted. Macau, due to the uniqueness of the sector that its listed companies is in, shows significant differences in its investments in research and development as against cities of mainland China. The comparability of its performance indicator is therefore relatively weak compared with other cities. This is also proven in the performance data.

Innovation and performance of listed companies in respective cities of the Greater Bay Area (2017)

Cities	R&D Intensity	ROA	ROE
Zhuhai	7.58%	7.18	25.62
Hong Kong	6.73%	3.37	9.21
Shenzhen	5.96%	2.06	14.55
Guangzhou	5.53%	4.16	11.23
Huizhou	5.06%	3.21	11.28
Zhongshan	4.34%	5.08	9.22
Jiangmen	3.76%	7.13	11.87
Dongguan	3.68%	5.66	10.84
Foshan	3.53%	8.05	17.93
Zhaoqing	3.03%	3.78	4.81
Macau	0%	5.79	30.88

Note: The data came from the financial terminal of Wind Information. ROA and ROE are measured with the weighted average method. The ROA is calculated by the weight of the overall assets of respective listed companies while the ROE is calculated by the weight of net assets of respective listed companies.

Among the cities with an R&D intensity of above 5%, their overall performance in the ROE is obviously above that of other cities. The unit asset profitability of listed companies in areas high in R&D intensity is above those low in R&D intensity, indicating that enhanced R&D intensity may improve the performance of listed companies through reinforced production efficiency, product quality, and product differentiation. ROA, on the other hand, is affected considerably by the industrial structure. Hong Kong, Shenzhen and Guangzhou all have a certain number of listed financial companies that are high in overall assets to result in relatively unimpressive performance in the ROA of cities that are high in R&D intensity. Therefore , effectively stimulating enterprises in the Greater Bay Area for them to improve the R&D intensity will to a certain extent improve the overall market performance and bring about a virtuous cycle for enterprises to constantly engage in innovation activities.

06

Chapter 6 Innovation Industry Comment Section

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Greater Bay Area
driving application innovation

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Being Innovative
Is to Keep Abreast of Times

Greater Bay Area driving application innovation

Zhou Jiangong
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This report presents a meaningful description and analysis of Chinese innovation by citing typical examples of Chinese companies and industries combined with data model analysis. The chapter on Guangdong, Hong Kong and Macao Greater Bay Area in particular, has provided considerable inspiration for me, for I have had some ties to this area.

During the 1990s I responded to Deng Xiaoping's rallying call and uprooted myself to this area after obtaining post-graduate qualifications. For more than 5 years I worked at Guangdong-Hong Kong Information Daily, one of the earliest business daily newspapers in China, and witnessed a 'golden era' for Guangdong, Hong Kong and Macao. In 2014 when I was working for the Chinese edition of "Forbes" magazine, the government of Shenzhen formally proposed a Bay Area economy. I was invited by Shenzhen municipal government and jointly held a forum on the subject. I can still remember clearly how the then party secretary and mayor of Shenzhen sat listening to my speech as I spoke. I was also invited to join the Advisory Committee on the Internationalization of Shenzhen. In all, I consider myself a 'Shenzhen resident'. During my stint at China Business Network, our company hosted the Tech & Innovation Conference in Shenzhen. The concept of Shenzhen Bay Area economy has evolved to become Guangdong, Hong Kong and Macao Greater Bay Area.

Bay Area economy was an ambitious concept. If there is a region in the world that can be truly called "the Bay Area", it would doubtlessly be the area consisting of San Francisco and Silicon Valley. This area boasts some of the best universities in the world, one of the greatest concentrations of capital, three of the world's five largest technology companies and countless unicorns and startups. From developing emerging industries to disrupting traditional ones, this is the Mecca of innovation, thinking and practice. Its 7.7 million-strong population consists of migrants from all over the world. It is also home to the world's 19th largest economy.

And then Guangdong, Hong Kong and Macao propose "the Greater Bay Area". To be called "Bay Area" economy, this region must be able to undertake the mission of innovation and growth.

There are three world-class cities in this Greater Bay Area: Hong Kong, the financial center, Shenzhen, the innovation center, and Macao, the entertainment center. Commercial center Guangzhou, at the center of the Pearl River Delta region, plays the role of "factory of the world". Guangdong, Hong Kong and Macao boast a natural cluster of world-class cities. It is almost impossible to find anywhere in the world, a city cluster that features financial center, technology and innovation center, an industrial and commercial center and an entertainment center. Today's Greater Bay Area possesses the impetus to achieve a world-class city cluster and innovation center. Nearly 70 million people live in the Greater Bay Area, giving it an economic scale that is equivalent to the world's 11th largest economic body.

How then should one realize the potential of the Greater Bay Area?

Openness and freedom. Hong Kong possesses the world's most liberal economy. For many years it has been among the highest-ranked free economies in the world. Its freedom is built on a mature legal governance and supervisory system. A free market economy, spirit of legal governance and service professionalism have all contributed to what Hong Kong stands for today, in the process helping the Pearl Delta region to be among the first in China to be assimilated into the global economy. They also influence Shenzhen to the extent that the city upholds competition and innovation.

Diversity and tolerance. The Greater Bay Area of Guangdong, Hong Kong and Macao features different political systems, social governance, development level and comparative advantages for industries in its main cities. An open internal system and integrated infrastructure are helpful in forming a regional economy that is diversified co-existence of cooperation and competition. Since China's reform and opening up, the Pearl Delta Region has assimilated tens of millions of workforce ranging from science & technology workers to manual laborers. Together they made up the engine of growth for economic development. "Migrant workers" to Shenzhen and Pearl Delta Region, including talents within the region, form an important source for the region's economic vitality.

Learning and innovation. Some industries in the Greater Bay Area such as electronic information, advance manufacturing and international trade now possess world-class competitiveness, in particular those that play the role of global hardware innovation and catalyst. The Greater Bay Area has also become one of the most important supply chain centers for global manufacturing. Both Shenzhen and the Pearl Delta Region have experienced a process of imitation and learning. They have now entered a phase of application

innovation with the emergence of a group of world-class enterprises like Huawei, Tencent, BYD and DJI. Companies in the Greater Bay Area possess inherent sensitivity to markets in all parts of the world. Manufacturers are able to rapidly respond to users' needs and ship their goods accordingly. The Greater Bay Area's unique competitive advantage is based on an innovation-based ecosystem that can quickly respond to and is driven by global market demand.

Education and talent. The greatest shortcoming of the Greater Bay Area lies in integration at a higher level of education and talents with industries. If it could be said that during the early stage of reform and opening up, Shenzhen and the Pearl Delta Region needed to attract talents from all over China that satisfy their short-term need of industrialization, then the Greater Bay Area would need to attract world-class talents and tertiary education for it to become a world-class innovation center. President Xi Jinping has said at China International Import Expo that China would open up its education. This is an opportunity for the Greater Bay Area. Hong Kong in the Greater Bay Area possesses top universities in Asia. Guangzhou is also home to a high concentration of tertiary institutions and talents. But the Greater Bay Area needs to have its own world-class tertiary education system. This can be achieved through opening-up. In particular the world's top universities and scientific research institutes can be attracted to set up base here by virtue of the area's strong industrial foundations and vibrant application innovation.

The greatest advantage of the Greater Bay Area, not least in Shenzhen, lies in the fact that it is on its way to forming a path of application innovation unique to China. Such innovation has its roots in an open and competitive market environment, an ability to imitate and learn as well as nimble development in keeping with global market demand, and enterprises' inherent research and development capability. As application innovation reaches a critical level, it will surely form an ecosystem comprising research and development prowess of large companies and innovation capacity of small and medium enterprises. Application innovation will eventually reach a higher plane of original invention and innovation. There are no constraints for the people of the Greater Bay Area. They are market-oriented, capable of applying as they learn and rapid renewal. They have evolved from small workshops to the world's factory and will surely be able to achieve a leap from "Made in China" to "Created in China".

The Greater Bay Area no longer needs to follow the path of the Bay Area to form a path of application innovation that is unique to China.

Being Innovative Is to Keep Abreast of Times

YangYanqing
Deputy Editor-in-chief of China Business News
Managing Director of Yicai Research Institute

Xiaomi Technology, which has newly listed, puzzles the capital market: Is it supposed to be a mobile phone maker or an internet company?

You will probably never find the answer if you seek for it from amid the information you have read in books. This is because innovation is changing familiar sectors in unexpected ways.

Not long ago, Ruth Porat, the chief financial officer of Google parent Alphabet, announced that commercialization of Waymo, Alphabet's self-driving project, had begun. Waymo started to test its pricing model so that users could pay to ride in its self-driving car.

This move was deemed a milestone commercializing autonomous cars and also a symbol of the transformation of the automobile industry in the artificial intelligence era. The manufacturer of the Waymo self-driving car is Fiat Chrysler Automobiles, but almost everyone knows it is a product of Google. System suppliers, built-in chip manufacturers, and high-performance battery producers will be the most important forces powering the industry In the self-driving period. None, however, is what we refer to now as an automobile service provider.

The boundaries of the familiar endogenous product chain and the exogenous industrial chain have undergone fundamental changes. Sci-tech firms, for example, are now breaking down the business structure of the insurance sector, cutting themselves a slice of the market. These originally endogenous product chains of insurance broke into respective exogenous industrial chains facilitating vertical access.

A future data company might marshal tens of thousands of robots in factories and instruct management. The big data analysis center has become the new brain behind medical institutions, while the operator of

the brain is a company of the ilk of IBM and iCarbonX.

Exogenous industrial chains, however, are quickly integrating.

The rise of platform-based companies is another characteristic of the new period. Large platform firms such as Alibaba Group Holding, Baidu, Tencent Holdings, Amazon, and Google have changed the overall terrain of commercial society. They they hold immense sway. They can be telecommunication companies, social network operators, e-commerce providers, financial companies, and game companies all at the same time. All these are made possible because of one or several formidable underlying platforms. Traditional enterprises are starting to look at these new business magnates that are emerging as new infrastructure in an almost spooked way. Even regulators have to reconsider whether antimonopolistic actions should continue to be labeled 'antitrust' or be replaced by the term 'contestability' in order to better reflect the definition in current economics.

Innovation is the greatest fuel powering the era, and the only tool capable of adapting to present circumstances. Innovation is not just about researching and developing new products or addressing a technical issue, but also about reshaping business models and ideas.

Every entrepreneur must take these changes seriously. If one in business only sees traditional industries and identifiable opponents, s/he is very likely to become the fish depicted by Picasso with just its bones, in the words of former IMF Vice President Zhu Min.

This is because innovation in today's world not only overcomes opponents, but is also the sole bulwark against utter obsolescence. ■

Appendix:

[1] Zhuang Lei, Zhao Cheng Guo and Zhang Chi defined in "Activating Industry 4.0: Empirical Study of Smart Equity Structure of Manufacturers" (2017) expounds that the ratio of intangible assets such as software as an indicator of an enterprise's "smart level."

[2] Equity concentration is calculated as:
Equity concentration = |the holding ratio of the biggest shareholder/holding ratioof Top 10 shareholders -1/2）×2|.

[3] The level of intangible assets is calculated as:
The level of intangible assets = 1 - net worth of tangible assets/total assets.

[4] Return on sales ("ROS") is calculated as:
Return on Sales (ROS) = net profit after tax/ business revenue

[5] The score of innovative environment is calculated as:

$$Y_i = (\sum_{i=1}^{3} w_i \times x_i) \times 10$$

In which x_1、x_2、x_3 are three indicators, namely, equity structure, popularity of innovation and government efficiency, respectively, after non-dimensionalization. w_i is the weight of Indicatori. In order to keep the score of innovative environment within the range of 0~100, it is multiplied by 10 on the basis of the equation.

[6] The score of innovative resources is calculated as:

$$Y_i = (\sum_{i=4}^{6} w_i \times x_i) \times 10$$

In which x_4、x_5、x_6 are three indicators, namely, investment in research and development, R&D staff and R&D intensity, respectively, after non-dimensionalization. w_i is the weight of the Indicatori. In order to ⏩

keep the score of innovative resources within the range of 0~100, it is multiplied by 10 on the basis of the equation.

[7] The score of innovative performance is calculated as:

$$Y_i = (\sum_{i=7}^{9} w_i \times x_i) \times 10$$

In which x_7、x_8、x_9 are three indicators, namely, IP level, level of intangible assets and sales margins, respectively, after non-dimensionalization. w_i is the weight of the Indicatori. In order to keep the score of innovative performance within the range of 0~100, it is multiplied by 10 on the basis of the equation.

[8] The innovation score is calculated as:

$$Y_i = (\sum_{i=1}^{9} w_i \times x_i) \times 10$$

In which $x_1 \cdots x_9$ are nine indicators, namely, equity structure, popularity of innovation, government efficiency, investment in research and development, R&D staff, R&D intensity, IP level, level of intangible assets and sales margins, respectively, after non-dimensionalization. w_i is the weight of the Indicatori. In order to keep the score of innovative environment within the range of 0~100, it is multiplied by 10 on the basis of the equation.

[9] Non-dimensionalization:

First, the industrial mean value is removed from respective indicators of independent variables in order to eliminate differences caused by the industry. Then, based on the formula below, the value obtained of all variables is kept within the range of 0-10 to facilitate estimation.

$$Z_i = (X_i - X_{min})/(X_{max} - X_{min}) \times 10$$

x_i means the No. x_i value observed of Independent Variablei; X_{max} and X_{min} are the maximum value and the minimum value of No. Z_i independent variable; and x_i is the value obtained after non-dimensionalization of x_i.

[10] Based on the evaluation system consisting of three elements, support, capacity, and value of the United Nations Development Programme , the Creativity Assessment Indicator System consisting of the three dimensions, namely, environmental support, resource capability and performance value are created for the cities in Guangdong-Hong Kong-Macao Greater Bay Area combining the characteristics of the cities and the actual innovative development in Guangdong, Hong Kong and Macao.

Creativity assessment indicator system for cities in Guangdong-Hong Kong-Macao Greater Bay Area

Primary Indicators	Secondary Indicators	Tertiary Indicators
Environmental support	1.1 Market structure	1.1.1 The ratio of small low-profit enterprises (%)
		1.1.2 The ratio of direct foreign investment in GDP (%)
	1.2 Industrial Foundation	1.2.1 GDP Scale (RMB 100 million)
		1.2.2 Total import/export value (RMB 100 million)
		1.2.3 Total industrial production output value of large scale and above (RMB 100 million)
	1.3 System-based Culture	1.3.1 Per-capita social insurance/protection (RMB/person)
		1.3.2 The number of libraries per ten thousand people
	1.4 Package support	1.4.1 Public land transportation efficiency (ten thousand people/day)
		1.4.2 Penetration rate of mobile Internet (%)
		1.4.3 The ratio of general hospitals in healthcare facilities (%)
Resource capability	2.1 Human resources	2.1.1 The net inflow of permanent residents (ten thousand people)
		2.1.2 The ratio of knowledge-intensive service sector in overall practitioners (%)
		2.1.3 The ratio of people with advanced education diplomas (%)
		2.1.4 The number of undergraduates of ordinary universities and colleges (ten thousand people)
	2.2 Capital investment	2.2.1 The ratio of expenditure on scientific technology in GDP (%)
		2.2.2 Expenditure on the development of new products of industrial enterprises of large scale and above (RMB ten thousand)
		2.2.3 Annual IPO scale (RMB 100 million)
		2.2.4 Market value of listed companies (RMB 100 million)
Performance value	3.1 Industrial performance	3.1.1 Per-capita GDP (RMB)
		3.1.2 Gross export value of high-tech products (RMB 100 million)
	3.2 Innovation performance	3.2.1 The number of domestic invention patents authorized
		3.2 .2 The number of PCT patents applied for every ten thousand people (the number of applications/ten thousand people)

Note: It is created on the basis of the entrepreneurship environment assessment system of the United Nations and the innovative environment assessment indicator system of the Organisation for Economic Co-operation and Development, with additional reference to 20 domestic and international assessment indicator systems such as the European Innovation Scoreboard, the GEDI Index, the Silicon Valley Index (U.S.), the World Knowledge Competitiveness Index and Entrepreneurship Index of Chinese Cities.