Historically an unremarkable fishing port, Shenzhen is now the richest major city in the country per capita, and China's most innovative metropolis.

NEIGHBOURS IN KNOWLEDGE

*Buoyed by government support, Shenzhen emulates
Guangzhou's academic excellence.*

BY HEPENG JIA

When it comes to basic research, Shenzhen has long been the little brother of neighbouring Guangzhou. The two cities are located 130 kilometres apart at the mouth of the Pearl River in China's richest province, Guangdong.

While Guangzhou's universities and public research institutes draw researchers and students from across the country, Shenzhen attracts technology and telecommunications titans such as Tencent and Huawei. But that dichotomy is beginning to change.

In 1980, the central government chose the small fishing town of Shenzhen to be the country's first special economic zone, which welcomed foreign and domestic investment without requiring the government's explicit approval. By 2016, Shenzhen's high-tech industries produced RMB784.7 billion (US\$116.8 billion) in revenue, accounting for 40% of the city's GDP. Just over 4.3% of its GDP went to R&D, the highest percentage after Beijing, amounting to more than RMB84 billion (US\$12.6 billion).

With 11 million residents, Shenzhen is now the richest major city in the country per capita. It is also China's most innovative metropolis. Huawei, for example, is the only Chinese company ranked in Clarivate Analytics Top 100 Global Innovators, and DJI Innovations Science and Technology has become the world's largest manufacturer of civilian drones. Both companies are based in Shenzhen.

"Shenzhen's market-driven economy and friendly environment has attracted innovative entrepreneurs, but, for a long time, it lacked local science and technology resources and talent," says Du Debin. Until about a decade ago Shenzhen had only one multidisciplinary university involved in research — Shenzhen University (SZU). And as it stands, SZU has not been recognized by the Ministry of Education as a national key university, which would give it extra funding and the pick of the country's top students. But in the past ten years, Shenzhen's academic research landscape has begun to gain ground.

FRIENDLY ADVERSARY

Guangzhou, the capital of Guangdong Province, has been at the centre of international trade since the 18th century. Guangzhou is home to most of the universities, professors and public research institutions in Guangdong.

In 2016, universities in Guangzhou took in more than one million undergraduate students — more than any other city in China, and 11 times more than Shenzhen. Sun Yat-sen University (SYSU) and South China University of Technology (SCUT) are among the top 50 institutions in China in the Nature Index. In 2016, Guangzhou had a weighted fractional count (WFC) of 228, more than double that of Shenzhen at 103.

However Guangzhou's R&D expenditure in 2016 — RMB45.7 billion (US\$6.9 billion) — accounted for only 2.3% of its GDP. That's about

GUANGZHOU WFC 2016: 228

SHENZHEN WFC 2016: 103

	Guangzhou	Shenzhen
Population ¹	14m	11.91m
GDP per capita ¹	US\$21,200	US\$25,400
R&D as % of GDP ²	2.3%	4.3%
R&D personnel ³	94,200	178,000
Patents granted ⁴	161	2,900

SHARE OF OUTPUT OVER TIME

City-level contribution to the share of authorship in the Nature Index, measured by the share of weighted fractional count (WFC) for that year, compared to China's share.

SUBJECT STRENGTHS

Guangzhou and Shenzhen contribute more to chemistry papers in the Nature Index than any other subject in the natural sciences.

1. Municipal Bureau of Statistics for each city (2016)
2. Guangdong Provincial Bureau of Statistics (2016)
3. Tong, A. et al. *Science and Technology Management Research* 3, 1000–7695 (2017) (2014 data)
4. United States Patent and Trademark Office (2016)

half of Shenzhen's R&D intensity.

"For decades, Guangzhou has been an important talent supplier to Shenzhen," says Wan Lu, an economist at Guangdong Academy of Social Sciences.

It also offers a constant stream of ideas. Investors based in Shenzhen, home to ChiNext, the Chinese version of the NASDAQ stock market, often invest in inventions and technologies developed by Guangzhou-based institutes.

For example, Shenzhen Capital Group bankrolled the mobile app start-up Mob.com, whose founders came from SCUT. Launched in 2012, Mob.com's services have been used on more than a billion devices worldwide. The city-pair's strongest co-authorship link in the Nature Index in 2016 was between the optical components company Shenzhen Star Optoelectronic Technology and SYSU in Guangzhou.

"We often collaborate with Guangzhou colleagues, because their academic disciplines and research devices are much more comprehensive than those available in Shenzhen," says Wu Xuli, a medical scientist at SZU College of Medicine. Guangzhou's medical institutes also offer a much larger database of patient information, he adds.

But Shenzhen has its own benefits. Scientists face less competition for grants, which are often larger. A typical grant in medical science, says Wu, is about RMB300,000 (US\$45,000) in Shenzhen, compared to RMB100,000 (US\$15,000) in Guangzhou.

GROWING UP

Shenzhen is beginning to come of age. In the last decade, researchers at its institutions have published dozens of papers in *Nature*, *Science*, *Cell* and *Physics Review Letters*, largely co-authored by researchers in the private sector. A major contributor to these papers has been the company BGI, a CAS spinoff and once the world's largest DNA sequencing provider for research.

"Although Shenzhen does not have many top universities, the pursuit of scientific innovation and market economy, together with the Shenzhen government's beneficial policies, attracted BGI to settle here in 2007," says Liu Xin, vice director of BGI Research, referring to the generous tax exemptions and low-cost land offered to high-tech firms. BGI's achievements include publishing a complete sequence of the giant panda, seahorse and carrot genomes, and conducting large-scale population analyses of the genetic basis of disease.

Physicists in Shenzhen have also benefited from their close proximity to the neutrino observation lab at the Daya Bay nuclear power plant, co-authoring a paper in *Physical Review Letters* in 2012, which found that neutrinos could oscillate from one state of mass to another to an unexpectedly large degree.

The Shenzhen municipal government has begun to use its financial clout to expand its research infrastructure. Between 2015 and 2016, it signed agreements with 10 universities, including SYSU, SCUT, Tsinghua University,

Peking University, and Harbin Institute of Technology, to either set up campuses in the city or upgrade their original teaching-focused graduate schools to independent campuses that foster research. The city offered the universities free land and financial subsidies for construction and salaries.

In 2009, Shenzhen established the research university Southern University of Science and Technology (SUSTech), which has promised to provide salaries equivalent to those in Western universities, with a minimum research start-up fund of US\$1.5 million over three years.

BILATERAL COLLABORATIONS

The number of bilateral partnerships between an institution in Guangzhou and an institution in Shenzhen has increased since 2012.

"FOR DECADES,
GUANGZHOU HAS BEEN
AN IMPORTANT TALENT
SUPPLIER TO SHENZHEN."

A 2012 study of 28 countries found that public universities in China paid on average one-tenth of the salary of those in Canada, the highest-paying country. "The establishment of these new university campuses will provide new fuel for Shenzhen's innovation," says Du. Within a short period of time, SUSTech has become Shenzhen's top-contributing institute to papers included in the Nature Index — its WFC has shot up from less than 1 in 2012 to 27 in 2016.

Not to be left behind, Guangzhou has also vowed to increase its R&D expenditure to 3% of GDP by 2020, as reported in its 13th five-year plan, released in 2016. Since 2015, it has worked with Shenzhen to build a Guangzhou-Shenzhen Science, Technology and Innovation Corridor, which aims to replicate Boston's Route 128. The corridor will integrate Guangzhou's academic research capacities with Shenzhen's technology development infrastructure, and manufacturing bases in industrial cities between the two municipalities. ■

TOP 10 INSTITUTIONS IN BEIJING

RANK	INSTITUTION	WFC 2012	WFC 2016	CHANGE IN WFC 2012–2016	AC 2016
1	Peking University	212.1	295.9	40%	1,130
2	Tsinghua University	178.6	252.2	41%	841
3	University of Chinese Academy of Sciences	65.0	127.2	96%	825
4	Institute of Chemistry, CAS	112.5	124.1	10%	382
5	Institute of Physics, CAS	81.3	76.1	–6%	294
6	Beijing Normal University	36.7	56.5	54%	188
7	Beijing Institute of Technology	15.2	44.4	192%	89
8	People's Liberation Army	31.9	42.4	33%	161
9	National Center for Nanoscience and Technology, CAS	24.9	38.4	54%	121
10	Technical Institute of Physics and Chemistry, CAS	26.5	36.7	39%	81

TOP 10 INSTITUTIONS IN SHANGHAI

RANK	INSTITUTION	WFC 2012	WFC 2016	CHANGE IN WFC 2012–2016	AC 2016
1	Fudan University	121.5	137.6	13%	363
2	Shanghai Institute of Organic Chemistry, CAS	103.9	103.8	0%	230
3	Shanghai Jiao Tong University	80.0	93.4	17%	424
4	East China University of Science and Technology	67.3	79.6	18%	168
5	East China Normal University	35.5	71.8	102%	149
6	Shanghai Institutes for Biological Sciences, CAS	45.7	58.8	29%	167
7	Tongji University	20.8	26.2	26%	89
8	Shanghai Institute of Materia Medica, CAS	19.9	24.7	24%	62
9	Shanghai University	21.9	24.3	11%	74
10	Shanghai Institute of Applied Physics, CAS	17.3	16.8	–3%	57

TOP 10 INSTITUTIONS IN GUANGZHOU

RANK	INSTITUTION	WFC 2012	WFC 2016	CHANGE IN WFC 2012–2016	AC 2016
1	Sun Yat-sen University	80.1	90.8	13%	271
2	South China University of Technology	31.4	56.4	79%	105
3	South China Sea Institute of Oceanology, CAS	10.4	15.9	52%	38
4	Jinan University	10.0	12.3	23%	44
5	South China Normal University	12.1	11.8	–3%	25
6	Guangzhou Institute of Geochemistry, CAS	3.8	8.0	108%	17
7	Southern Medical University	1.8	6.1	238%	19
8	Guangzhou Institutes of Biomedicine and Health, CAS	14.3	5.1	–64%	18
9	Guangzhou Medical University	1.2	5.0	304%	24
10	South China Agricultural University	1.7	3.5	107%	15

TOP 10 INSTITUTIONS IN SHENZHEN

RANK	INSTITUTION	WFC 2012	WFC 2016	CHANGE IN WFC 2012–2016	AC 2016
1	Southern University of Science and Technology	0.6	27.3	4,295%	76
2	Peking University Shenzhen Graduate School	1.9	25.2	1,215%	47
3	Shenzhen University	2.4	14.7	507%	54
4	Shenzhen Institutes of Advanced Technology, CAS	11.6	6.1	–48%	28
5	Graduate School at Shenzhen, Tsinghua University	0.0	5.4	n/a	17
6	BGI	11.8	5.3	–55%	34
7	HKU Shenzhen Institute of Research and Innovation	0.0	2.7	n/a	16
8	HKUST ShenZhen Institute	0.0	2.4	n/a	12
9	Shenzhen Research Institute, PolyU	0.0	2.2	n/a	9
10	City University of Hong Kong Shenzhen Research Institute	0.0	1.8	n/a	11

TOP 10 COLLABORATIONS IN BEIJING

RANK	INSTITUTION 1	CS 1	INSTITUTION 2	CS 2	TOTAL CS
1	Peking University	88.86	Institute of Chemistry, CAS	96.87	185.72
2	Peking University	50.42	Tsinghua University	44.84	95.26
3	Peking University	37.58	Institute of Physics, CAS	35.87	73.45
4	University of Chinese Academy of Sciences	22.55	Institute of Chemistry, CAS	46.99	69.54
5	Tsinghua University	28.11	Institute of Physics, CAS	35.51	63.61
6	University of Chinese Academy of Sciences	13.60	National Astronomical Observatories, CAS	32.06	45.66
7	Peking University	19.89	University of Chinese Academy of Sciences	22.50	42.39
8	Peking University	11.73	National Astronomical Observatories, CAS	14.10	25.83
9	University of Chinese Academy of Sciences	8.76	Institute of Biophysics, CAS	16.43	25.19
10	Beijing Normal University	14.89	Peking University	10.10	24.99

TOP 10 COLLABORATIONS IN SHANGHAI

RANK	INSTITUTION 1	CS 1	INSTITUTION 2	CS 2	TOTAL CS
1	Fudan University	22.11	Shanghai Jiao Tong University	6.24	28.35
2	Shanghai Jiao Tong University	8.96	Shanghai Institutes for Biological Sciences, CAS	6.70	15.66
3	East China Normal University	10.79	Shanghai Institute of Organic Chemistry, CAS	2.74	13.53
4	East China University of Science and Technology	6.66	Shanghai Institute of Organic Chemistry, CAS	4.51	11.17
5	ShanghaiTech University	1.15	Shanghai Institutes for Biological Sciences, CAS	9.81	10.96
6	Fudan University	5.00	Shanghai Institutes for Biological Sciences, CAS	5.25	10.24
7	Fudan University	4.39	Shanghai Institute of Organic Chemistry, CAS	4.86	9.25
8	East China University of Science and Technology	4.73	Shanghai Jiao Tong University	4.04	8.77
9	University of Chinese Academy of Sciences, Shanghai	2.26	Shanghai Institutes for Biological Sciences, CAS	6.41	8.67
10	East China University of Science and Technology	1.24	Shanghai Institutes for Biological Sciences, CAS	6.55	7.78

TOP 10 COLLABORATIONS IN GUANGZHOU

RANK	INSTITUTION 1	CS 1	INSTITUTION 2	CS 2	TOTAL CS
1	Guangzhou Medical University	2.26	Guangzhou Institutes of Biomedicine and Health, CAS	2.21	4.46
2	South China University of Technology	2.31	Sun Yat-sen University	1.94	4.24
3	Guangzhou Medical University	0.45	Sun Yat-sen University	2.47	2.92
4	Jinan University	0.73	Sun Yat-sen University	1.70	2.44
5	Sun Yat-sen University	1.48	Guangzhou Institutes of Biomedicine and Health, CAS	0.34	1.82
6	South China Normal University	0.60	Sun Yat-sen University	1.10	1.70
7	South China Agricultural University	0.49	Sun Yat-sen University	1.10	1.59
8	Guangzhou Medical University	0.04	Southern Medical University	0.96	1.00
8	Guangzhou University of Chinese Medicine	0.14	South China Agricultural University	0.86	1.00
8	South China University of Technology	0.83	Guangdong Provincial Academy of Chinese Medical Sciences, CACMS	0.17	1.00
8	Sun Yat-sen University	0.88	Guangzhou Institute of Geochemistry, CAS	0.13	1.00
9	Jinan University	0.25	South China Sea Institute of Oceanology, CAS	0.67	0.92
10	Jinan University	0.64	Guangzhou Institutes of Biomedicine and Health, CAS	0.27	0.91

TOP 10 COLLABORATIONS IN SHENZHEN

RANK	INSTITUTION 1	CS 1	INSTITUTION 2	CS 2	TOTAL CS
1	Peking University Shenzhen Graduate School	1.17	Southern University of Science and Technology	0.83	2.00
2	Graduate School at Shenzhen, Tsinghua University	0.31	Peking University Shenzhen Graduate School	1.21	1.52
3	Shenzhen University	0.38	Shenzhen Institutes of Advanced Technology, CAS	0.54	0.92
4	Southern University of Science and Technology	0.61	Longgang Central Hospital, Shenzhen	0.22	0.83
5	Peking University Shenzhen Graduate School	0.18	Shenzhen Institutes of Advanced Technology, CAS	0.59	0.77
6	HKUST ShenZhen Institute	0.25	Peking University Shenzhen Graduate School	0.50	0.75
7	Graduate School at Shenzhen, Tsinghua University	0.56	Shenzhen University	0.19	0.74
8	Shenzhen University	0.60	Southern University of Science and Technology	0.07	0.67
9	Peking University Shenzhen Graduate School	0.61	Shenzhen University	0.04	0.64
10	Graduate School at Shenzhen, Tsinghua University	0.50	Shenzhen South China Pharmaceutical Co., Ltd	0.11	0.61