

Fraunhofer ISI Discussion Papers *Innovation Systems and Policy Analysis*, No. 19

ISSN 1612-1430

Karlsruhe, July 2009

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**Chinese Regional Innovation Systems  
in Times of Crisis –  
The Case of Guangdong**

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## Abstract

The dynamic economic development of Guangdong province is one of the most prominent examples of China's catch-up in the course of the past two decades. Once chosen as the nation's first experimental field for the market economy, the province continued to participate above average in national economic growth ever since. Up to today, it maintains a leading position with regard to general industrial performance and average personal income. As China's industry begins to embark on a path of technological upgrading, however, this pre-eminent position begins to be challenged. In the nation's emerging fields of strength, the province's rivals, Beijing and Shanghai, are in a better starting position since they are better endowed with both R&D capacities and qualified human capital. In this context, our paper illustrates the resulting challenges by means of a number of specialized indicators and explains why, despite a continuously impressive export performance in the high-tech sectors, Guangdong is far from well prepared to maintain its current position. Finally, it briefly describes the policy responses that have been developed, concluding that – despite clear evidence of progress – some key issues with regard to regional innovation policy appear to remain unaddressed.

## 1 Introduction

Industrial development in the province of Guangdong has been the driving force of China's economic catch-up since the early stages of the opening-up and reform policy in the 1980s. At that time, Guangdong became the national experimental field for China's successful FDI and growth strategy based on labor cost advantages. Three of the first five special economic zones (SEZs), where foreign companies were allowed to establish their assembly operations, were located in Guangdong (Lu/Wei 2007). Additionally, the geographical and cultural proximity to well developed Hong Kong helped to turn the Pearl River Delta (PRD) into a particularly thriving "backyard workshop" (Enright et al. 2005). Based on these favorable conditions, Guangdong rapidly became the richest non-urban province in China, and, until today, remains among the main drivers of national economic performance. In particular, this is the case with a view to the world market. While it accounts for only 7.0% of the population and 12.5% of total GDP, 31.5% of all Chinese exports originate from Guangdong. In its relative importance for the Chinese economy, it is thus second only to the Yangtze River Delta (i.e. Shanghai, Zhejiang and Jiangsu), with a GDP share of 22.6% and an export share of 39.1%.

The sustainability of the current regional export-based wealth and competitiveness, however, has become an issue of concern, as in practice it remains strongly based on labor cost advantage (Kroll/Schiller 2008). Currently, Guangdong contributes only 10.9% to the national total of intramural R&D (cf. Table 4), i.e. less than its share in overall economic activity, let alone exports.

As a consequence of their extensive export orientation based on labor cost advantage, companies in Guangdong proved particularly vulnerable to the external shock emanating from the 2008 financial crisis. In the first quarter of 2009, the value of imports and exports declined by 23.1% compared to the previous quarter and, even worse, by 85.6% compared to the first quarter of 2008. Soon, more than a quarter of the province's enterprises were making losses (14,292 out of 43,728 firms) and overall economic profits have decreased by 33.7% compared to the last quarter of 2008 (Statistics Bureau of Guangdong Province 2009c). Nevertheless, the general production value in Guangdong continued to increase by 5.8% in relation to the last quarter of 2008. This, however, still implies a decrease of about 4.7% compared to last year (Statistics Bureau of Guangdong Province 2009a).

More than ever before, the current crisis has thus exposed Guangdong's vulnerability and dependency on export-based assembly production. While other export-dependent nations have also been hit by the crisis, many of them have suffered less. In summary, recent events have demonstrated that, while robust to a degree, the Guangdong economy needs structural repositioning if a sustainable reduction of its vulnerability is to be achieved. Based on this very current challenge, this paper will consider the province's options to embark onto a different, more innovation-based path of development suitable to reduce its future vulnerability. Additionally, it aims to assess whether the current innovation policy appears suitable and conducive to achieve this strategic target.

## **2 Foundations of Guangdong's International Competitiveness**

Quite often, external observers are impressed by China's rising exports and positive trade balance in the field of high-tech commodities (Table 1) <sup>1</sup>. This first impression, however, has to be put into perspective as, indeed, many high-tech goods are exported, but the trade balance is not sufficiently positive to indicate a substantial degree of technological competencies at the regional level. As Table 2 clearly illustrates, the situation in Guangdong is characterized by re-assembly of imported technological goods into final products, such as computers. While provincial figures are not available, national high-tech trade statistics illustrate that more than 75% of all high-tech goods exported from China are in fact based on local assembly of imported components.

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1 "High-Tech Products" definition based on the High-technology Products Statistics Catalog published by the Ministry of Science and Technology and the Ministry of Commerce, covering computers and telecommunications; life science; electronics; computer-integrated manufacturing; aerospace; opto-electronics; biotechnology; materials; and others. According to the NBS, it is compatible with the US export and import catalog for Advanced Technology Products. ([www.sts.org.cn/sjkl/gjscopy/data2008/data08.htm](http://www.sts.org.cn/sjkl/gjscopy/data2008/data08.htm)).

In Guangdong, the import to export ratio of foreign invested enterprises (which cover about 80% of all trade in the field of data processing equipment) was around 0.85 for electric and electronic products and around 0.75 for high-tech products, e.g. computers. Again, as to be expected, the imports of 'Electronic Technology' were 4.7 times higher than the exports. In itself, this situation is not necessarily problematic, but natural as a stage in the process of technological upgrading. At the current stage of development it can be understood as evidence of the ability to process complex imported goods, i.e. as evidence of a rising technological competence and absorptive capacity. Nonetheless, it strongly suggests that most technological exports from the province are in fact still based on the re-assembly of imported components. Other than intuitively expectable, there is thus no basis for the assumption that the region's high-tech export performance would in any way be related to local R&D capacities in either the regional firms or the local public research sector.

Our conclusion, therefore, is that, in this specific context, the mere turnover of high-technology goods is unsuitable as a measure of regional technological capabilities and the province's competitiveness in the world market so that its technological potential has to be assessed by other means.

**Table 1: Chinese Trade Balance in High-tech Products (in US \$ bn)**

	2001	2002	2003	2004	2005	2006
Export	46.5	67.9	110.3	165.4	218.3	281.5
Import	64.1	82.8	119.3	161.3	197.7	247.3
Balance	-17.7	-15.0	-9.0	4.0	20.5	34.2

Source: China S&T Statistics Data Book 2007 (MOST 2007)

**Table 2: Guangdong's Trade Balance in High-tech Goods**

10,000 US\$	Import	Export	Balance
Parts of semi-conductor devices	640,546	155,461	-485,085
Circuit protection devices	545,889	418,360	-127,529
Integrated circuits and parts of electronic components	<b>4,920,595</b>	392,650	-4,527,945
Data processing equipment	989,411	<b>4,110,387</b>	3,120,976
Color TV sets	3,597	284,235	280,638
Display boards with LCD or LED screens	n/a, small	46,260	ca. 46,000
Laser vision disc players	n/a, small	597,508	ca. 597,000

Source: Statistics Bureau of Guangdong Province (2009b)

**Table 3: Composition of China's Export of High-tech Products (in US \$ bn)**

	2002	2003	2004	2005
General trade	4.1	6.6	9.9	13.1
Processing with supplied materials	11.5	16.5	24.8	32.7
Processing with imported materials	49.5	82.7	124.0	163.7
Others	2.7	4.4	6.6	8.7
Total	67.9	110.3	165.4	218.3

Source: China S&T Statistics Data Book 2006 (MOST 2007)

### 3 R&D Activities in Guangdong Province

Even though R&D in the enterprise sector may not yet be the foundation of the province's international competitiveness, and not yet very relevant in absolute terms, Guangdong is the unrivalled center of current business expenditure on R&D in China. Generally speaking, one fourth to one third of all R&D activities in the Chinese high-tech industry are performed in the province of Guangdong. A significant share of this expenditure is accounted for by two large private firms: Huawei (Low 2007) and ZTE. Nonetheless, the data suggest that an increase in investment from "other" sources may indicate increasing R&D investment by small and medium-sized enterprises that do not fit into the official LME classification.

Additionally, the local industrial sector is the relatively most important R&D performer in the province. Other than in the Beijing capital region and to an at least distinctly lesser extent than in the Yangtze River Delta, most local R&D activities are performed in the enterprise sector (cf. Table 4). The relative contribution of higher education institutions, in contrast, remains below the national average and amounts to only half the share typical in Beijing or the Yangtze River Delta. Government funding for S&T which amounts to 42.9% in Beijing and a remarkable 22.1% on national average, reaches only 10.6% in Guangdong. To a degree, however, a below average spending on public R&D can also be observed in the Yangtze River Delta (20.9%).

Time series data show that the dominance of the industrial sector in Guangdong has continuously increased in the course of economic development. While during the last fifteen years expenditures for public research could be increased more than fourfold; R&D expenditures in the large and medium-sized enterprise sector have risen even more substantially – close to 50-fold. In short, although only a small fraction of this sector performs such activities, Guangdong's key role on the national stage is almost exclusively based on R&D activities performed in the local industrial sector. Overall, there is very little public R&D in the province and the lion's share of the remarkable growth in R&D efforts has to be attributed to the technological upgrading of the enterprise sector.

**Table 4: Intramural Expenditure for R&D by Performing Actors 2007**

	Total (billion Yuan)	(share)			
		Independent Research Institutions	Large and Medium-Sized Enterprises	Higher Education Institutions	Other
<b>China total</b>	371.0	18.5%	56.9%*	8.5%	16.0%
Beijing	50.5	<b>47.0%</b>	12.1%*	9.4%	31.4%
Yangtze River Delta	101.9	11.5%	<b>63.5%*</b>	7.5%	17.5%
<b>Guangdong</b>	40.4	2.8%	<b>83.2%*</b>	3.7%	10.4%

\* Chinese surveys only cover firms with more than 300 employees, more than 40 million Yuan assets and more than 30 million Yuan sales on an annual basis. Small firms (accounting for about 8% of R&D activities) are covered every 5 years but detailed results are not made public. Source: China Statistical Yearbook on Science and Technology 2008 (National Bureau of Statistics 2009a)

## 4 Sectoral Differentiation of R&D Expenditure in the High-tech Industry

Contrary to the regional specialization in terms of exports, Table 2 illustrates that Guangdong's industrial research and development system is not very specialized in 'Computer and Office Equipment Manufacturing' or 'Medical and Pharmaceutical Products as well as Measurement Equipment'. Instead, such specializations are found in the provinces of the Yangtze River Delta and even Beijing.

In the province of Guangdong, in contrast, R&D expenditures are highly – almost solely – directed towards the subsector of 'Electronic and Telecommunication Equipment'. This strong sectoral specialization in a single field is a distinct feature of the Guangdong innovation system and can to a great extent be attributed to the R&D activities of a single large firm, Huawei in Shenzhen (Low 2007). This telecommunication firm is singular in being a Chinese private enterprise with a substantial amount of turnover that continuously invests more than 10% of its revenue in R&D. In 2006, with 8.8 billion RMB, more than a third of all industrial R&D expenditures in the province could be attributed to Huawei (2008: 16 billion RMB).

Overall, this example shows how fragmented and fragile the basis of innovative activities in the local business sector still is. While the total figures may at first sight convey a picture of substantial and broad-based capabilities, this changes substantially when a few major firms are taken out of the calculation.



**Table 5: Intramural Expenditure for R&D in High-tech Industry 2007**

	<b>total</b> (million Yuan)	Medical and Pharmaceutical Products Manufacturing	Aircraft and Spacecraft	Electronic and Telecommunica- tion Equipment	Computer and Office Equip- ments Manufacturing	Medical Treat- ment Instrument and Meter Manufacturing
<b>China total</b>	54,532	12.1%	7.8%	59.5%	15.0%	5.6%
Beijing	2,899	8.4%	<b>12.1%</b>	36.6%	<b>35.9%</b>	7.1%
Yangtze RD	15,952	<b>15.4%</b>	2.0%	<b>56.6%</b>	<b>16.3%</b>	<b>9.7%</b>
<b>Guangdong</b>	18,011	3.2%	0.4%	<b>81.1%</b>	13.4%	1.9%

Source: China Statistical Yearbook on High Technology Industry 2008 (National Bureau of Statistics 2009b)

## 5 Nature of R&D Expenditure in the Guangdong High-tech Industry

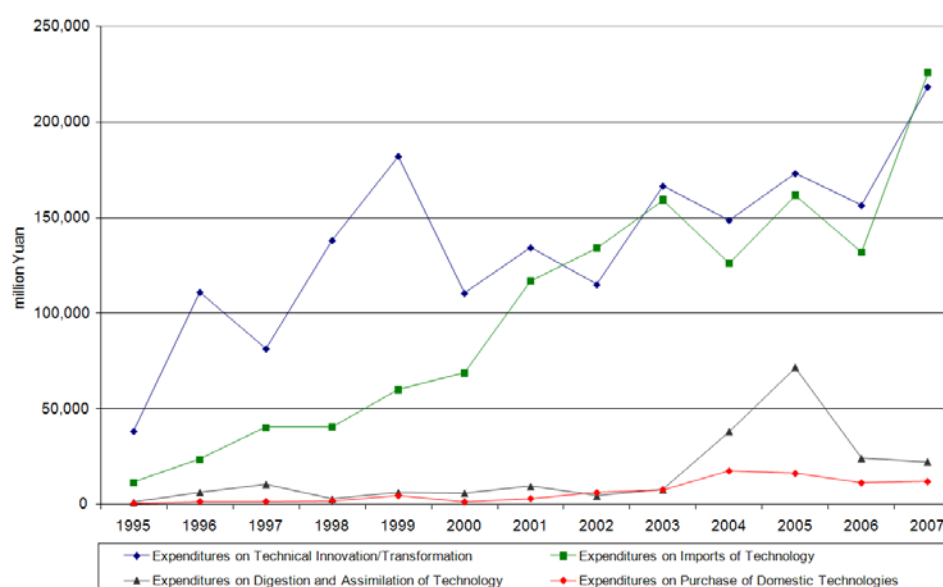
Table 6 and Figure 1 illustrate that an increasing amount of R&D expenditure in Guangdong is allocated to in-house R&D activities ("technological innovation/ technological transformation"). According to data from official statistics, however, this expenditure continues to co-evolve with spending on the import of foreign technology. While expenditure for local technological innovation and transformation continues to rise, it remains closely matched by expenditures for technological imports (cf. Table 6 and Figure 1). Taken together with the expenditures for the assimilation of (likely imported) technology, they even surpass the amount of funds allocated to in-house R&D activities. The acquisition of domestic technologies, in contrast, continues to play a minor role even though it has more than doubled in recent years.

Remarkably, this situation is different on national average where both trends co-evolve in a similar way, but expenditure on technology imports remains much lower. In the Yangtze River Delta, moreover, expenditures on technology imports have dropped below those for in-house innovation since 2003 and now amount to little more than 60%. Likewise, Beijing has seen a peak of imports from 2004-2006, but in general ranks below Guangdong. It thus appears that – more than other Chinese regions – Guangdong remains dependent on international technology transfer to upgrade its technological capabilities.

**Table 6: Relation of Expenditure for Technology Import to Expenditure for In-house R&D**

	1995	2000	2003	2004	2005	2006	2007
National average	0.35	0.45	0.60	0.60	0.53	0.46	0.62
Guangdong	0.30	0.62	0.74	0.63	0.93	0.84	1.03
Beijing	0.12	0.38	0.24	0.78	1.72	2.14	0.72
Yangtze River Delta	0.26	0.86	1.01	0.60	0.66	0.40	0.63

Source: own calculation, based on China Yearbook of High Technology Industry 2008 (National Bureau of Statistics 2009b)

**Figure 1: S&T Expenditure in the High-tech Industry of Guangdong Province**

Source: own diagram, based on China Yearbook of High Technology Industry 2006 & 2008 (National Bureau of Statistics 2007; 2009b)

## 6 Technological Activities and Technological Profiles

### 6.1 National Patent Applications

An analysis of national patent applications at the State Intellectual Property Office (SIPO) identifies Guangdong as the Chinese province with the largest absolute number of patent applications (see Table 4), far ahead of Beijing – even though it cannot match the three provinces of the Yangtze River Delta taken together.

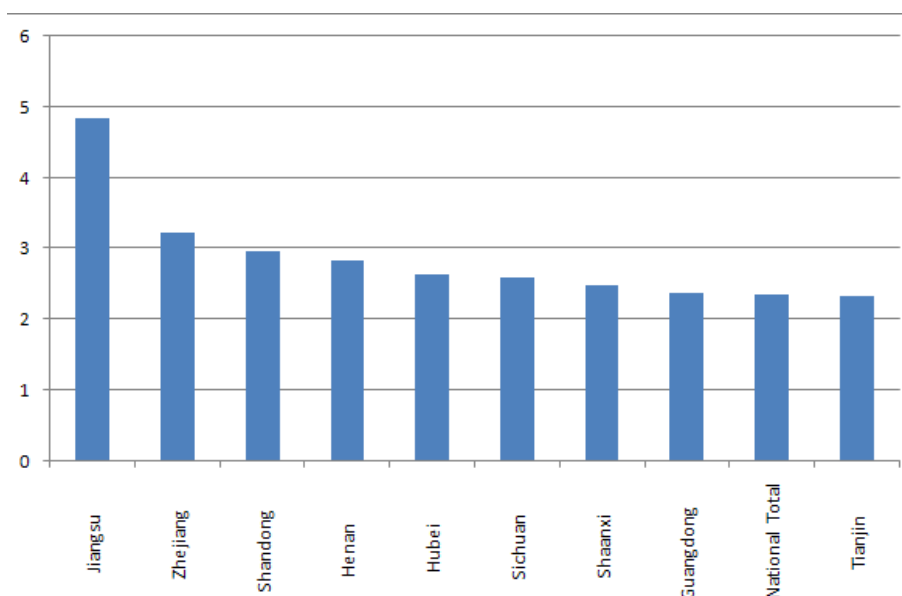
Nonetheless, Table 4 also illustrates some shortcomings as only about 26.1% of the total number of patent applications are invention patents rather than mere utility models ('utility patents') or industrial designs ('design patents').

This figure corresponds to the Chinese average of 26.1%, but lies far behind other provinces and municipalities like Beijing (59.2%), Tianjin (34.1%) or Shanghai (32.2%). Apparently, research that results in inventions with a degree of novelty high enough to provide the basis for an application for a genuine patent is less frequent in Guangdong than in many other regions. Although the share of invention patents originating in Guangdong (17.4%) is the largest among all regions and municipalities in China, this should not obscure the fact that the average relevance of inventions made in Guangdong remains below the expected level with a view on its export figures and below that in its emerging rival region, the Yangtze River Delta. Additionally, while the number of regional patent applications has grown substantially (2.37 times) in the last five years, it has grown even stronger in the Yangtze River Delta (cf. Figure 2). Moreover, the basis of local activity is fragile, as again more than 25% of regional invention patents are applied for by a single firm: Huawei.

**Table 7: National Patent Applications of Selected Regions, 2007**

	Absolute Numbers				Relative Numbers (in percent)		
	Total	Invention	Utility	Design	invention	of total invt	of total
Guangdong	102449	26692	25389	50368	0.2605	0.1744	0.1747
Beijing	31680	18763	8819	4098	0.5923	0.1226	0.0540
Jiangsu	88950	16578	16586	55786	0.1864	0.1083	0.1517
Shanghai	47205	15212	12112	19881	0.3223	0.0994	0.0805
Zhejiang	68933	9532	19270	68933	0.1383	0.0623	0.1175
Shandong	46849	8795	19106	18948	0.1877	0.0575	0.0799
Liaoning	19518	5516	8012	5990	0.2826	0.0360	0.0332
Tianjin	15744	5364	5117	5263	0.3407	0.0350	0.0268
Hubei	17376	3705	7168	6503	0.2132	0.0242	0.0296
Sichuan	19165	3406	5205	10554	0.1777	0.0223	0.0327
Henan	14916	2875	5571	6470	0.1927	0.0188	0.0254
Fujian	11341	2170	3878	11341	0.1913	0.0142	0.0193
Hunan	11233	3670	4158	3405	0.3267	0.0240	0.0192
Shaanxi	8499	2412	2779	3308	0.2838	0.0158	0.0144

Source: SIPO; Fraunhofer ISI calculations

**Figure 2: Growth of SIPO Applications in Selected Regions 2002-2007 (2002=1)**

Source: SIPO; Fraunhofer ISI calculations

## 6.2 Transnational Patent Applications

As Figure 2 illustrates Guangdong seems to be falling behind its emerging rivals in China with regard to relevant national patent applications. Therefore, it appears necessary to analyze its performance with regard to patents of international relevance that allow us to assess the region's technological competitiveness on the international stage. To do so, the concept of Transnational Patents will be used (Frietsch/Schmoch 2007; Patel/Frietsch 2007). As illustrated by Table 5, the absolute numbers of patent applications are still very low for China as well as for Guangdong – even though growth rates are high.

Generally, Guangdong is very active in high-tech areas and leading-edge technologies (i.e. such with high levels of re-investment in R&D) with a particularly outstanding position in the field of electrical engineering, or more precisely in information and communication technologies (ICT). In the years from 2003 to 2005, more than 45% of total Chinese patent applications at the transnational level originated from Guangdong.

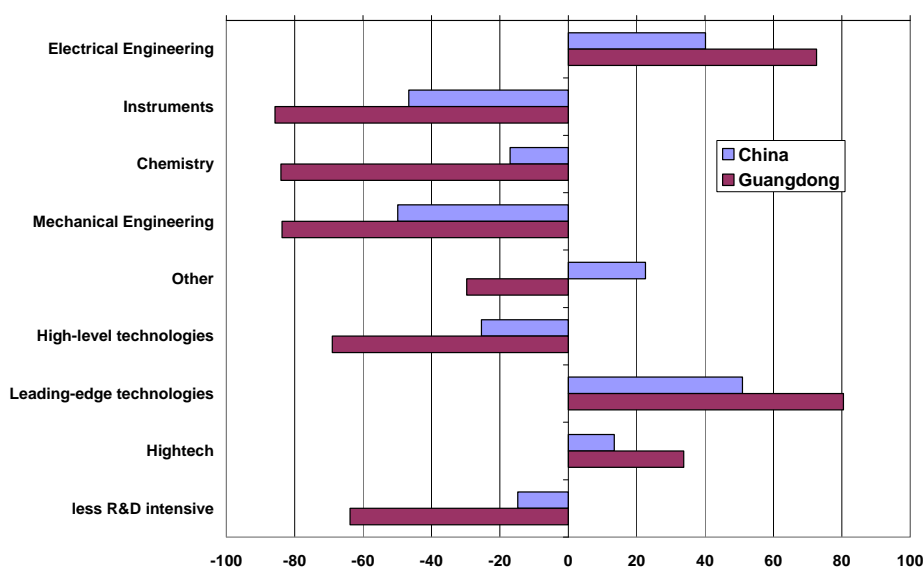
Figure 3 summarizes these findings based on the specialization index, the comparison of relative strengths and weaknesses beyond size effects that confirms a strong specialization in electrical engineering and, as a consequence, in the aggregate high-tech field. In contrast, Guangdong is underspecialized in most other areas, indicating a narrow dominance of one technological field. With regard to transnational patents, the focus is even stronger: more than 60% (!) were applied for by Huawei between 2003 and 2005.

**Table 8: Absolute and Relative Numbers of Transnational Patent Applications, 1996-98 vs. 2003-05**

	Electrical Engineering	Instruments	Chemistry	Mechanical Engineering	Other	High-level technologies	High-tech Leading-edge technologies	Total High-Tech	less R&D intensive
Absolute Numbers 2003-2005									
China	4557	934	2109	1122	1205	2706	3773	6479	2554
Guangdong	2057	118	203	159	194	413	1800	2213	383
Growth (comparison of the periods 1996-98 and 2003-05)									
China	18.8	8.1	5.4	5.6	5.8	6.7	16.4	10.2	6.4
Guangdong	137.1	59.0	11.3	9.9	14.9	14.9	246.5	63.2	15.3
Shares of Transnational patents in 2003-2005 (in percent)									
Guangdong / China	45.1	12.6	9.6	14.2	16.1	15.3	47.7	34.2	15.0

Based on empirical findings and international conventions, high-tech areas are defined by the share of turnover that is – on average – re-invested in R&D (Grupp et al. 1996; Legler/Frietsch 2007). High-tech areas can be further differentiated into high-level and leading-edge technologies. High-level technologies are those that reach R&D investment shares of 2.5-7.5%, whilst leading-edge technologies usually require investments of more than 7.5% (Grupp et al. 2000; Legler/Frietsch 2007).

Source: STN: EPFULL; Fraunhofer ISI calculations

**Figure 3: Technological Specialization Profile of Guangdong, 2003-2005**

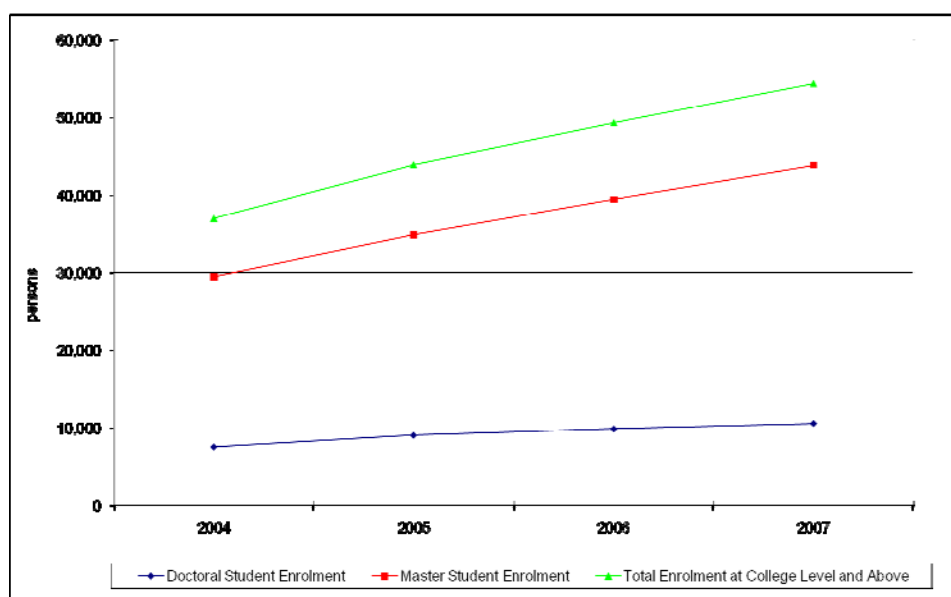
Source: STN: EPFULL; Fraunhofer ISI calculations

## 7 Human Capital Base

There is no doubt that Guangdong province has made impressive progress in strengthening education and human capital, as illustrated by Figure 4. In terms of total R&D personnel, Guangdong has caught up with Shanghai, Jiangsu and Zhejiang, and remains second only to Beijing (MOST 2007). In terms of R&D personnel per population, however, Guangdong continues to lag far behind Beijing and Shanghai as well as the Yangtze Area with 16 employees per 10,000 inhabitants, in contrast to 107 in Beijing and 27 in the Yangtze Area (National Bureau of Statistics 2009a). Additionally, the province of Guangdong lacks nationally renowned universities and research centers (Arvanitis/Jastrabsky 2006). Among the 20 most productive Chinese universities in terms of publications only one (Zhongshan University) is located in the area (Frietsch et al. 2008). Moreover, Guangdong has only four S&T-based universities educating the researchers most needed for high-tech development and advanced manufacturing – compared with 12 in Shanghai, 18 in Jiangsu province and 8 in Zhejiang province.

Furthermore, its undergraduate enrolment in science and engineering is below the national average. Likewise, Guangdong ranks below the national average in terms of the overall education level, such as the share of people possessing more than a college degree. In the long run, such an insufficient supply of human resources cannot satisfy the demand of Guangdong's industry, however focused it may be, and impairs Guangdong's ability to lay the foundations for future innovation-based development (Cai et al. 2004; Statistics Bureau of Guangdong Province 2009b).

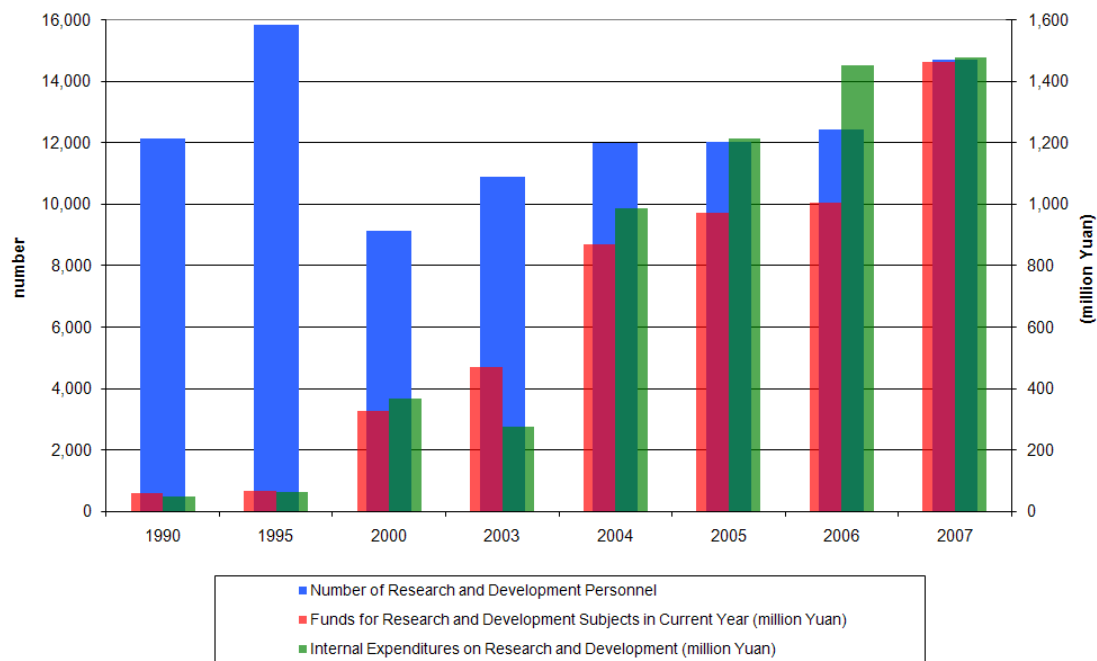
**Figure 4: Guangdong Postgraduates in Thousands: 2004-2007**



Source: Statistics Bureau of Guangdong Province (Statistics Bureau of Guangdong Province 2008; 2009b)

Notably, however, investment in higher education research which had grown only moderately in the early to mid 1990s increased remarkably in the last five to ten years, likely due to the establishment of the Shenzhen Virtual University Park. Despite that, investment in higher education in Guangdong has decreased by 0.2% between 2005 and 2006. Generally speaking, the current status of the provincial scientific and research base cannot keep up with the pace of upgrading in industry.

**Figure 5: R&D Personnel and R&D Funding in Institutions of Higher Education in Guangdong**



Source: own diagram, based on Statistics Bureau of Guangdong Province (2009b)

## 8 Scientific Performance

Although there has been impressive growth of scientific output (i.e. number of scientific papers published) and many efforts have been made in this respect, the scientific foundation of Guangdong province remains insignificant, both in absolute terms and in national comparison. In relation to China's total scientific output, Guangdong only reaches an average level of 3.5%, the maximum being 4.6% in medicine and the minimum 2.3% in the field of electrical engineering.

Furthermore, as Table 9 illustrates, both China and Guangdong generate the highest share of their absolute scientific output in chemistry and engineering. In the key areas of technological and economic activities, in contrast, scientific output remains very moderate (e.g. 188 publications in electronic engineering, 487 in computer science).

**Table 9: Absolute and Relative Numbers of Scientific Publications, 2004-2006**

	EE	CO	OP	MS	CH	ME	MB	EC	Total
<b>Chinese Publications</b>	8,102	15,459	13,959	43,070	64,315	69,313	51,772	38,416	304,406
<b>Guangdong Publications</b>	188	487	518	1,254	2,577	1,930	2,359	1,428	10,741
<b>National share of Guangdong</b>	2.3	3.2	3.7	2.9	4.0	2.8	4.6	3.7	3.5

EE: electrical engineering; CO: computers; OP: optics, measuring, medical equipment; MS: material science; CH: chemistry; ME: mechanical engineering, physics; MB: medicine, biology; EC: ecology, geoscience, other

Source: STN: SCISEARCH; Fraunhofer ISI calculations.

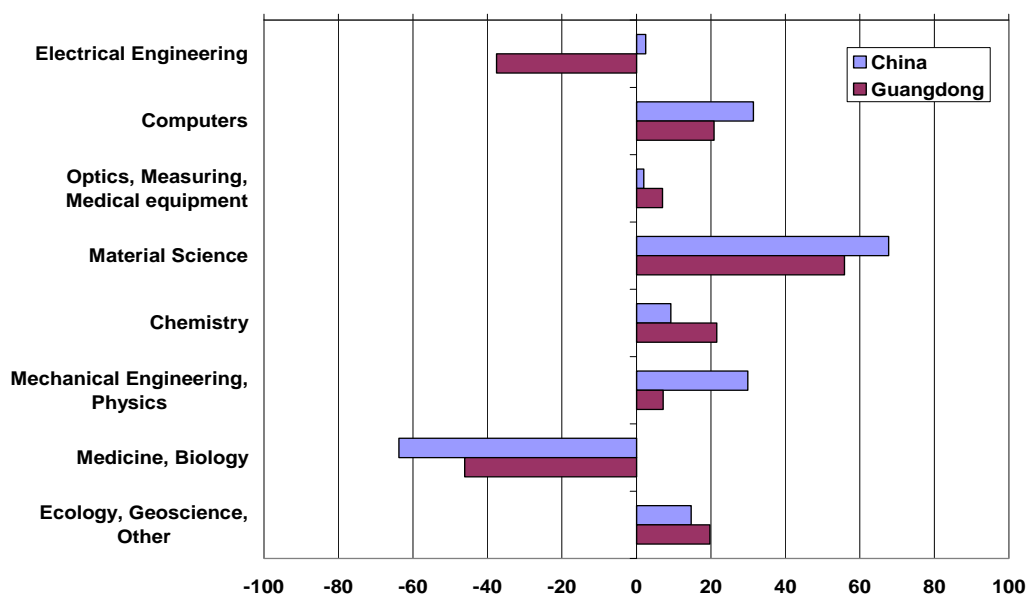
In Figure 6, the RLA specialization index is displayed – a measure that allows the assessment of fields and countries beyond size effects. While it reveals a relative regional strength in material science and chemistry, it emphasizes the weak position in medicine and electrical engineering – the area of greatest local investment in private R&D.

On the other hand, the industrial sector in Guangdong has been more involved in scientific activities than the national average level in most research fields. This is especially true in the fields of optics, pharmacy and environmental engineering. Table 5 shows industry participation in scientific research in Guangdong and China. In the research field of optics, for example, the proportion of publications with co-authorship from an industry sector is more than six times the national average. Further examination, however, reveals that most of the firms listed in the optics publication list are foreign-owned companies or joint ventures, which is in line with the above suggestion that most regional R&D activities beyond Huawei are still dominated by foreign enterprises (e.g. Comba Telecom System Holdings Ltd and E-O National Co., Ltd).

Similarly, about 19% of all scientific publications of Guangdong are co-authored with at least one international researcher (Table 8). The Asian-Pacific area – i.e. Japan, South Korea, Singapore, Australia and other countries of this region – are most important as collaborative partners for Guangdong province. However, as the largest knowledge-producing economies in the world, the USA and Europe, too, are of substantial interest for Guangdong authors. While co-operation with the Asian-Pacific countries dominates in electrical engineering, computing, material science, optics, and mechanical engineering, the US are the dominant partner of co-operation in medicine and chemistry and match the Asia-Pacific Region in ecology. Europe, on the other hand, is not a dominant partner in any field (coming closest to that status in chemistry).



**Figure 6: Profiles of Scientific Specialization of China and Guangdong, 2004-2006**



The specialization index RLA (Revealed Literature Advantage) is defined as:  $RLA_{kj} = 100 * \tanh \ln [(P_{kj}/\sum_j P_{kj})/(\sum_k P_{kj}/\sum_{kj} P_{kj})]$ . with  $P_{kj}$  indicating the number of publications of country  $k$  in field  $j$ . Positive/Negative values point to the fact that the field has a higher/lower weight in the portfolio of the country than its weight in the world.

Source: STN: SCISEARCH; Fraunhofer ISI calculations

**Table 10: Industry Involvement in Scientific Research: Guangdong vs. China, 2004-2006**

Research Field	CN Industry Publications	CN Industry Publ. in %	GD Industry Publications	GD Industry Publ. in %
Materials research	789	3.4	51	5.1
Basic chemistry	523	2.0	46	3.5
Biology	239	1.1	45	3.0
Biotechnology	216	1.2	38	3.3
Multidisciplinary	396	1.8	32	2.9
Mechanical engineering	471	3.5	25	5.3
Medicine	203	0.7	25	1.2
Electrical engineering	267	4.4	22	8.8
Physics	276	1.3	22	2.3
Pharmacy	122	1.6	21	4.8
Computers	209	1.8	15	2.8
Optics	58	1.2	14	7.4
Polymers	103	2.0	13	3.2

The identification of industry sectors is based on authorship affiliation and an industry thesaurus which clusters affiliation name endings with industry symbols such as "Corp", "Co.", "Ltd" etc.

Source: STN: SCISEARCH; Fraunhofer ISI calculations

**Table 11: International Co-publications with Selected Regions and Countries, 2006-2008**

	EE	CO	OP	MS	CH	ME	MB	EC	Total
<b>USA</b>	26	38	46	62	<b>322</b>	179	<b>608</b>	<b>237</b>	1518
<b>Asian-Pacific</b>	<b>43</b>	<b>59</b>	<b>63</b>	<b>152</b>	288	<b>237</b>	347	<b>238</b>	1427
<b>EU-27</b>	27	42	42	73	237	157	338	152	1068
<b>UK</b>	17	22	25	22	59	47	135	55	382
<b>Germany</b>	3	7	3	16	34	42	45	37	187
<b>Total</b>	116	168	179	325	940	662	1473	719	4582

Source: STN: SCISEARCH; Fraunhofer ISI calculations

## 9 Strengths and Weaknesses of Guangdong

As the pioneer of China's economic reform, Guangdong has a 30-year tradition of economic achievement and accumulated valuable experience. Due to this first-mover advantage and its continuous labor cost advantages in the international markets, Guangdong remains among the group of leading provinces in China. Based on their long-standing tradition of world market orientation, many local actors are well positioned and have sufficient absorptive capacity to import capital, technology and ideas that they exploit locally (Kroll/Schiller 2008). Nonetheless, the effects of the favorable factors that Guangdong enjoyed in its past have clearly diminished and cannot be built on forever. With the increasing competition within China, especially the emergence of the Yangtze River Delta as the dominant player on the national stage, Guangdong is gradually but clearly losing its past preeminent position (Cheng et al. 1998; Zhang/Zhou 2006).

Our analysis has demonstrated that, for the time being, the foundations on which the province could be developed into a truly innovative economic region are weak. Mostly they rest on the efforts of foreign-invested firms in the electronics and telecommunications sector and one or two large Chinese actors, Huawei and ZTE. Despite its past achievements and, in the Chinese context, the remarkable degree of innovative activity in the private enterprise sector, significant structural challenges remain ahead.

In summary, it was the key purpose of this section to illustrate that due to its continued reliance on the processing of imported goods without substantial local capabilities, Guangdong's economic situation remains highly vulnerable to external economic shocks since, beyond a few exceptions, its industrial sector remains characterised by a lack of technological capabilities and a shortage of complementary local scientific excellence to draw on. Consequently, a continuation of the mostly labor cost advantage based policies of the past would in the mid-term pose an additional danger to a region that is already struggling to maintain its position in an upgrading Chinese economy.

## 10 Innovation Policy in Guangdong

Since the mid 1990s, the Guangdong government has acknowledged the need for continuous technological upgrading, and started to develop policy instruments to stimulate the transition from a manufacturing powerhouse to a sustainable regional economic development center with a leading position in China. In May 1998, the Guangdong provincial government released a Report titled "On the decision to rely on scientific and technological progress to attain a higher level of production in Guangdong". Guangdong also initiated its "10 Top Projects" in 2006, and plans to invest more than 1000 billion Chinese Yuan in infrastructure, the automobile industry, environment protection, high-tech development, and cultural development in the five years following 2006. In addition to national innovation policy, in 2006, the provincial government passed the *Measures on Promoting Independent Innovation*, including measures such as preferential taxes and direct subsidies.

In its *11th 5-year plan (2006-2010)* and the regional *Mid- to Long-term Science and Technology Plan for 2006-2020*, Guangdong provincial government reiterates its determination to realize an innovative economy.

Beyond mere proclamations, these policy efforts have achieved first results. In late 2006, there were 249 national and provincial Engineering Research and Development Centers in Guangdong, 135 national and provincial Enterprise Technology Centers, 117 key laboratories above the provincial level, and 108 town platforms for technical innovation. In the first ten months of 2006, applications and granting of patents for inventions had increased to 69% and 31%, respectively. According to the *Annual Report of Regional Innovation Capability of China: 2005-2006*, the overall innovation capacity of Guangdong was ranked in 3rd place in recent years (RGDSS&T of China 2006).

Moreover, the provincial government has analyzed its own weaknesses quite thoroughly since 2007 and as a result put in place a whole bundle of new policies to overcome the current problems. Most interestingly, the Guangdong government propounds the advantage of the financial crisis as one of the biggest chances for Guangdong's economy to transform from the old model of low-cost production to an innovation- and knowledge-driven economy. The government of Guangdong released a few documents on its new innovation policies since 2008. These papers make it clear that the provincial government is moving towards a much more integrated way of policy-making, funding distribution as well as seeing the current global financial crisis as a means to change the industrial structure of Guangdong province more quickly than would have been possible before. As described in the official documents No. 74, 2008 "*The outline of Guangdong's plan for indigenous innovation*" and No. 72, 2008 "*The announcement of the practical outline of building an innovative Guangdong Province*", the local government announced an integrated policy between the Science and Technology De-

partment and the Education Department of the Ministry. In order to address the most pressing weaknesses of the province and with the final goal of strengthening the international competitiveness of industry in Guangdong, the government defined 9 key areas of political action. According to government plans, Guangdong shall strive to re-establish its status as a national experimental field, this time to become the forerunner for indigenous innovation. Nonetheless, attracting innovative investments from different sources, including Hong Kong, Macao, and foreign investment, remains high on the agenda (Statistics Bureau of Guangdong Province 2009c).

In general, policy support will be targeted both at projects aiming to achieve "high-tech breakthroughs" and at enterprises aiming to increase their innovation capabilities. A clear focus is put on the establishment of innovation networks between industry, universities and research institutes in order to strengthen their co-operation for innovation. Moreover, emphasis is given to the training and education of high level innovative professionals and the establishment of excellent and innovative research groups in Guangdong, including the search for leading scientists in other regions of China as well as internationally. The Guangdong government sees a strong need to actively reform the science and technology system and to establish new and modern research institutions. Another policy shift occurred with regard to the final aim of research, development and innovation, as now all technologies have to serve the people's wellbeing and livelihood, e.g. in the field of health (Guangdong Provincial Government 2008).

Another important area of action is the implementation of Guangdong's intellectual property rights strategy and technology standards strategy.

In the related fields of infrastructure, demand, legislation etc., a number of clear goals were set. Besides completing the respective laws for innovation policies, the provincial government established a policy for its own governmental departments to invest in innovation. Investment in innovation will grow more rapidly than any other investment of each department, and shall be in accordance with the laws. This includes the introduction of a funding success evaluation system and should raise the efficiency of S&T funding in Guangdong.

In February 2009 another, even more detailed, official document was released (No. 22, "The announcement of the work to increase investment strength, strengthen innovation and support a stable and fast economic development"). It refers to the "Outline of the Pearl River Delta reform and development plan (2008-2020)" as well as some conferences on science and technology at the national level. According to this official paper, the Guangdong Department for Science and Technology will set up a special fund to increase innovation activities in the province for the period from 2009 to 2012. The strategic goal of this fund and the related policy are to raise investment in indigenous innovation, to concentrate financial resources, and to invest government funds in such a

way that a multiplier effect can enhance government spending. To implement this policy and to use this fund, the Guangdong government identified 10 big innovation projects for the next three years. One of these 10 projects is the support for 100 big companies, which have strong innovation capabilities, possess highly skilled innovative talents, and are able to work in open innovation networks as well as in close cooperation with universities and research institutes. These companies will be accompanied by technology innovation platforms and related applied technology research institutes in industries which are of key importance for Guangdong, e.g. digital information, new materials, bio medicine, satellite navigation, energy saving and new energy, marine technologies, consumer electronics, textile and clothing, equipment manufacturing, food, construction materials, automobiles, petrochemicals and fine chemicals, Chinese medicine, paper making, and modern logistics. Another project is the intensification of research in the province as well as the promotion of the closer linkages and networks between research and enterprises. This comes together with the plan to establish more independent research institutes, including the re-organization or merging of existing ones, which serve the public as well as industry. These research institutes will play a leading role at the national level, too (Guangdong Provincial Government 2009). This of course might be a more ambitious goal, as so far the number of outstanding research institutions is relatively low in Guangdong, compared to Shanghai or Beijing and competition is quite severe between the prosperous provinces of the east.

Policy measures of Guangdong province government also include the neighboring regions of Hong Kong and Macao, which are strongly connected with regard to trade. Recent policy plans are going so far as to address the three regions jointly as one harmonized regional innovation system, called the "Guangdong, Hong Kong and Macao Innovation Circle". There are several rather concrete plans for implementation, including the establishment of the Hetao Innovation Park for Micro Electronics, Ocean Innovation Park for advanced machinery, Nansha City – Guangdong – Hong Kong Science and Technology Innovation Park, co-operations with the Hongkong Science and Technology University, CAS Guangdong Industrial S&T Institute, Nansha S&T Information Park, South China University of Technology Nansha Science Park, to name but a few. The most important industries to benefit from this measure are electronic information, Chinese medicine and creative industry. Besides these industries, the Guangdong government sets a focus on projects in the areas of bio medicine and health (including food safety and a new agricultural industry), new materials for saving energy and energy conservation, the development of a new energy resource industry (including high efficiency solar cells, electricity generating systems etc.), equipment manufacturing, and green lighting industry (LED, OLED and develop packaging industry around the lighting industry). Finally, the provincial government acknowledges and aims to address its weakness in knowledge-intensive business services. Consequently, one of the 10 big projects is specifically aimed at the establishment of an S&T service industry. The

main implementation projects are the establishment of new high technology development areas, incubators and science parks, but also include technology transfer centers, and an initial design center for products made and designed locally.

Besides these 10 big projects, the Guangdong government has also realized that innovation happens in a regional system and cannot be regarded in a linear fashion, as was traditionally assumed. In 2009 the Guangdong government is paying much attention to the close link between science, technology, research, development and government funds. For the first time, 4 cities have been chosen to become pilot cities for science and technology funds, with some major reform pilot projects carried out to intensify the close linkage of government S&T funds with the S&T capital market of the region. In order to reach a multi-level S&T funding system in Guangdong, effective mechanisms to share the risk between the cities and the province will be established. This will be accompanied by the establishment of a new bank for S&T funding, especially designed for the needs of Guangdong's innovative enterprises to invest more in innovation and development projects. Additionally, the Guangdong Department for Science and Technology has set up a "fund for new high technology industry", which complements the special fund (with its sub-funds) to support SME development by the provincial government. In 2009, the Guangdong government will spend 2.2 billion RMB out of this special fund to support innovative SMEs in Guangdong (Guangdong Provincial Government 2009).

In summary, the rules and regulations for spending innovation support funds seem to illustrate a new political approach. Firstly, the Guangdong government actively promotes the distribution of its innovation funds with tenders, indicating a move away from the traditional discretionary allocation of funding to a much more competitive funding procedure. Secondly, the government is using its policy to increase scale effects of its funds, trying to link up with the science and technology capital market of the province and surrounding areas. Thirdly, they focus on increasing the efficiency of spending, which was neglected in the past.

## **11 The New Innovation Policies in Summary**

Apparently, the government of Guangdong province has adopted a more systemic view on innovation policy and in 2008 made many efforts to integrate the policies of the Education Department with the Science and Technology Department.

Firstly, with regard to the development of a stronger knowledge creation base, Guangdong seems to be on the right way, as the government introduced many different policies, ranging from the establishment of new research institutes, reforming the university structure, inviting foreign research and teaching institutions to the province, to the attraction of highly qualified staff from in and outside of China to serve as a base for fur-

ther knowledge creation as well as for institutional development. Moreover, the regional government launched a number of policies to strengthen the mobility of its scientists and workforce. The goal of these policies is to improve the transferability of certifications and working permissions and to reduce the boundaries between universities, research institutions and industry. On the other hand, the creation and development of intermediate agencies that help the actors to actually connect with each other has been neglected. In a region where public research and industry are working very independently of each other – so that links among them do not develop naturally, this can be considered as a serious gap in policy design.

Secondly, the government cashed in its promise to make the industrial sector the main target of innovation policies. A number of different financial incentives and funding programs were launched to effectively motivate SMEs, LMEs and MNEs to invest more in corporate R&D. Moreover, a trend towards a more competitive allocation of these funds can recently be observed.

Thirdly, while committing to the national goal of promoting innovations which are mainly created in China, policy makers maintain a clear commitment to international cooperation. The provincial government seems to have realized that in a province as foreign dominated as Guangdong the strongest potential for domestic upgrading must be based on international technology transfer for some time to come. Consequently, it is addressing the prevalent lack of absorptive capacity in the local industrial sector.

Fourthly, however, venture capital remains scarce in Guangdong and the provincial government does not seem to put a great deal of effort into its further development. Instead, it concentrates on building up special banks, which adapt their financial instruments to the special needs of innovative enterprises, particularly for the SMEs.

Finally, IPR and standardisation policies have been put on the agenda, but it seems that the implementation is still rather weak.

## **12 Summary and Conclusions**

Often it is argued that a more systemic governance of innovation policy, in which many different stakeholders and framework conditions are targeted and which addresses multiple issues in the fields of a) education, b) research, c) financial policy/tax policy, d) framework legislation and e) industry policy in a holistic and integrated manner is needed to improve the innovation system in Guangdong. Certainly, this is true and an internalization of this approach was a first and inevitable step on the road towards the modernization of innovation policy in Guangdong province. Consequently, and rightfully, the innovation policy measures recently implemented by the Guangdong government are regarded as exemplary best practice throughout the country

Nonetheless, many questions relating to the issue on which basis the desired local "system of innovation" could be established and which are the most pressing issues in this regard, remain unanswered.

Apparently, the provincial government has acknowledged one key challenge: that the local provision of relevant public research results is a necessary ingredient for future competitiveness. On the other hand, there has so far been a lack of clear statements regarding how the more daunting regional challenge is to be addressed: The severe regional overspecialization in a single field: electronics and telecommunications, that to a large degree rests on a single firm. Both in times of economic crisis and with a view to future sustainable competitiveness, a broader technological foundation is needed to reduce risks and prevent possible shocks in the regional economy. Only if this problem is addressed can the province be prepared for future challenges and – possibly – catch up with its former position on the national stage.

So far the development of closer linkages between industry, education, science and research has remained a political wish rather than become a reality. As in other countries, the implementation of such political strategies faces a number of obstacles, as goals, attitudes, values, education and language of industrial managers and scientists differ enormously from each other. In many cases, moreover, due to their labor-cost-oriented business models, industrial firms do not see any benefit in these politically intended networks and cannot imagine how to reap any benefit from them.

While the 10 big projects approach seems fruitful in that it clarifies on which size group of enterprises the provincial government will focus its efforts (on LMEs), the chosen spectrum of 16 fields of technology appears far too broad to develop sufficient financial momentum in the individual fields to create a counterbalance to the all-dominating electronics sector. It is not feasible that relevant structural change can be achieved unless the focus is limited to two or three fields.

Even though government policies greatly emphasize the problem of scientific staff and talents, it appears rather unlikely that the mismatch between industrial demand and higher education personnel supply will diminish in the near future.

Finally, it is left unclear to what extent international enterprises will be allowed to participate in the process and how exactly the development of absorptive capacity in the local firms is to be supported. However, the support for joint innovative projects with actors from Hong Kong is a positive sign, as Hong Kong firms contribute up to 75% of all foreign investment in the region. If the firms that are so far continuing to use Guangdong as a workshop could be motivated to raise their currently very low technological activities, this could easily pave the way for the much needed structural change.



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