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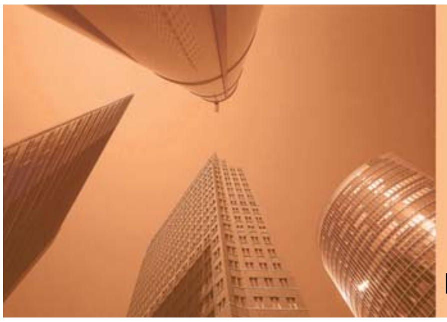

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The Regional Development of Science and Innovation in China

– A Brief Review of Current Evidence on Matches and Mismatches –

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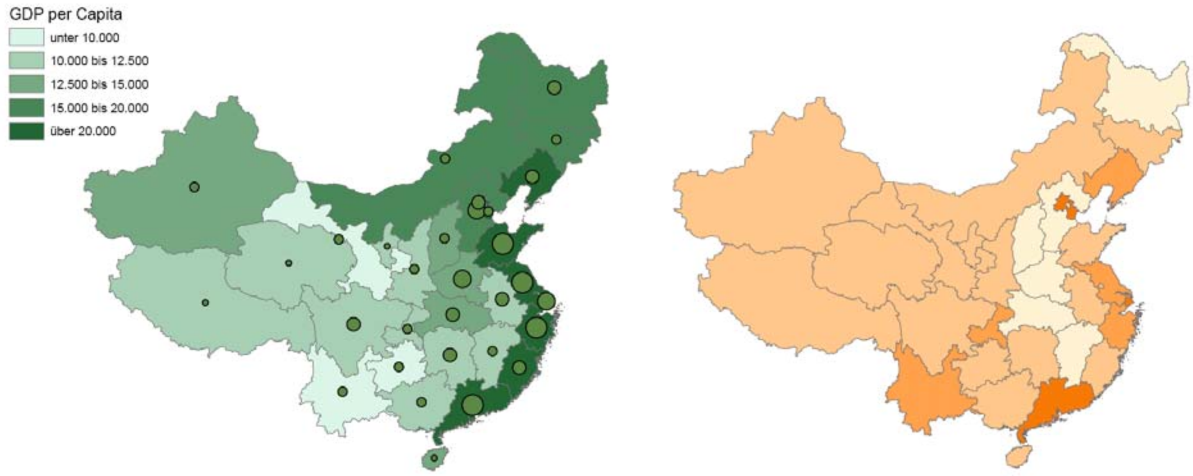
Introduction

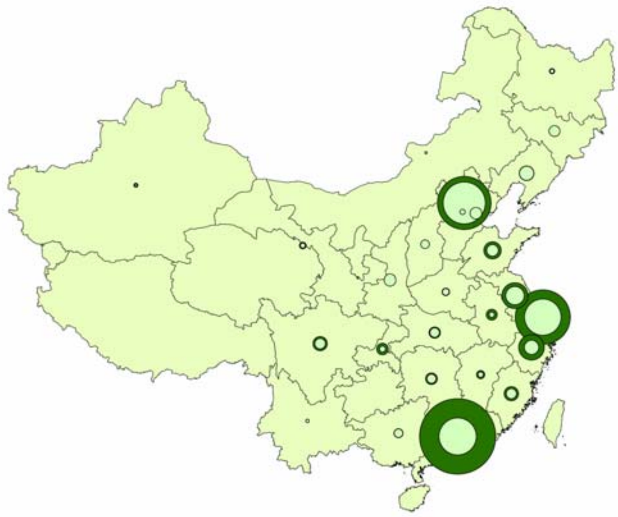
While a number of Chinese technology firms start to become visible on the international markets, the technological capabilities in the broader industrial sector remain at a moderate level. Economic growth continues to depend to a substantial degree based on upgraded but still labour intensive production. Figure 1 illustrates that most economic potential is concentrated in the export oriented coastal provinces. The distribution of average wages, however, shows that only a small portion of this potential can be based on well-paid high-qualified jobs. To the contrary, average industrial wages in some of the wealthiest provinces remain below those further inland, as visible in Figure 1. Moreover, as Figure 2 illustrates, internationally relevant technological achievements (documented by EPO patent applications) remain overwhelmingly concentrated in the first tier centres of Beijing, Shanghai (Yangtze River Delta) and increasingly Guangdong (Pearl River Delta). In a country with as high a degree of economic differentiation and independence in regional policy as China, therefore, all debate about innovation merits regional differentiation.

Figure 1: Distribution of GDP per capita and Average Urban Industrial Income in China



Source: China Statistical Yearbook, Fraunhofer ISI cartography

Figure 2: EPO Patent Applications in China 2000-2002 (light green) and 2003-2005 (dark green)

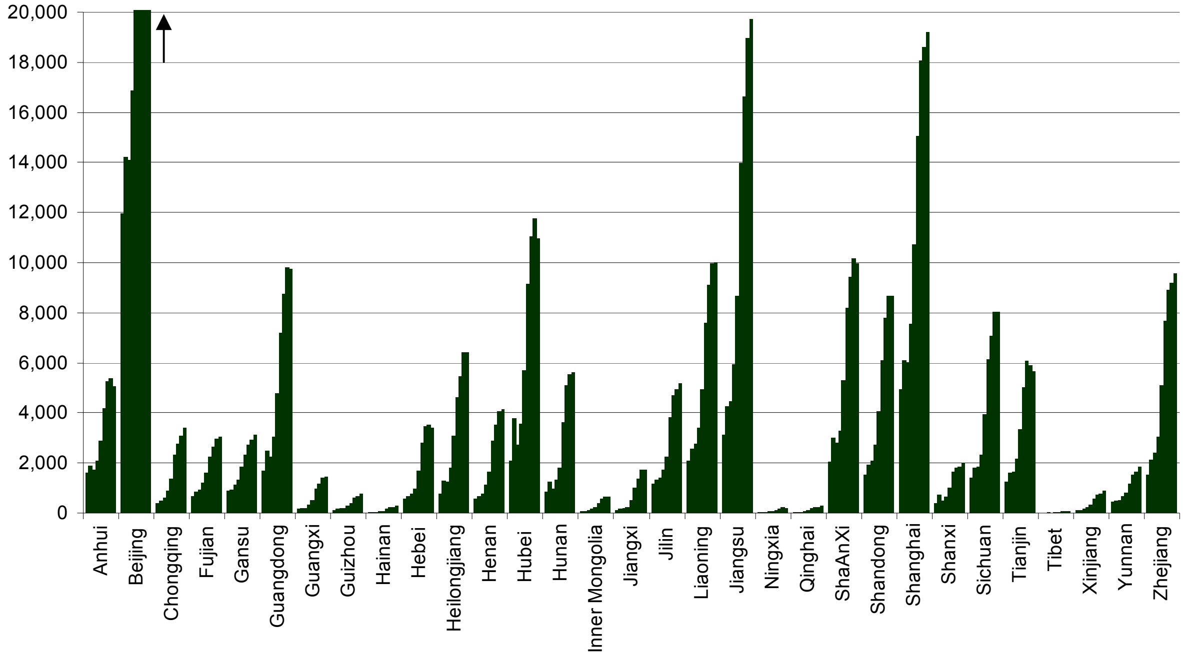


Source: Patstat Database, Fraunhofer ISI calculations & cartography

During the past decade, however, both publication activities and patent applications at the Chinese national patent office (SIPO) have substantially increased in a greater number of provinces (cf. Figure 3 and Figure 4) suggesting that a broader surge in technological capability building activities is about to emerge. If the Chinese economy continues to develop at its current pace those efforts may start to bear fruit in the coming years. Already today, second tier regions have reached a substantial share in S&T activities of national relevance.

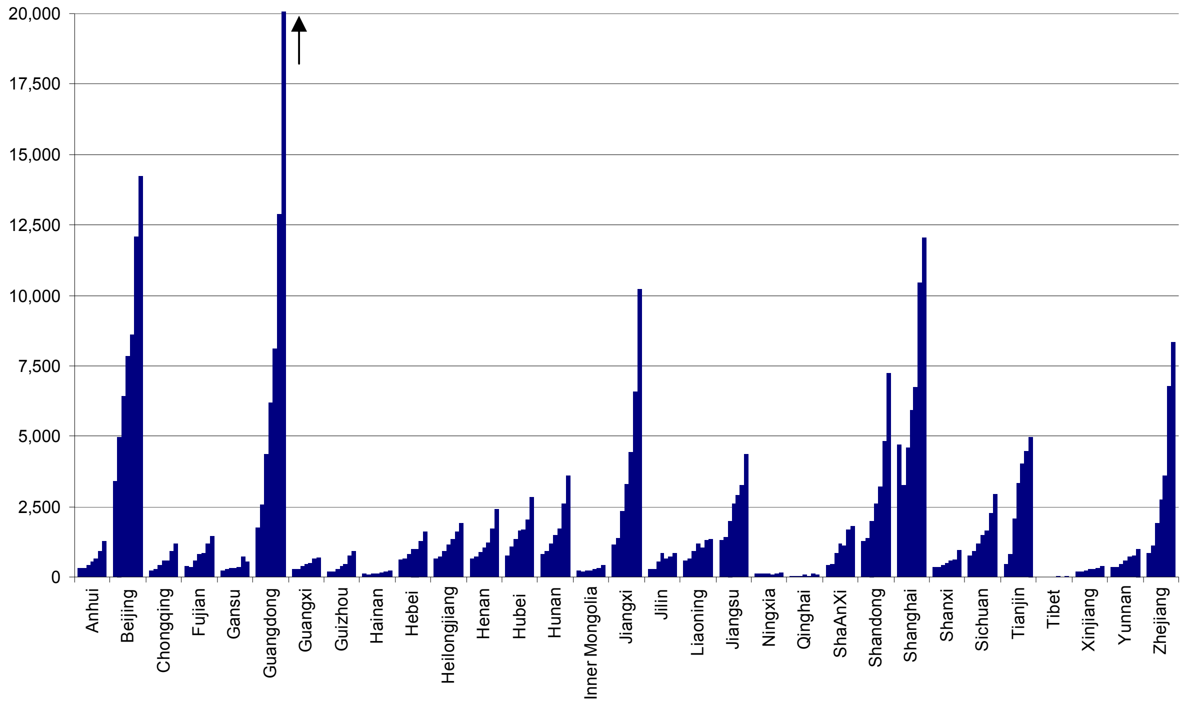
While, measured by Gini-Index, national technological activities (evidenced by SIPO patent applications) still tend to display a trend towards further regional concentration, the regional dispersion of scientific activity (evidenced by publications) has been significantly reduced, even despite Beijing's continued role as a determining centre.

Figure 3: Growth of Publication Activity 2000-2006



Source: Elsevier Scopus Database, Fraunhofer ISI calculations & diagram

Figure 4: Growth of Patent Applications at SIPO 2000-2006

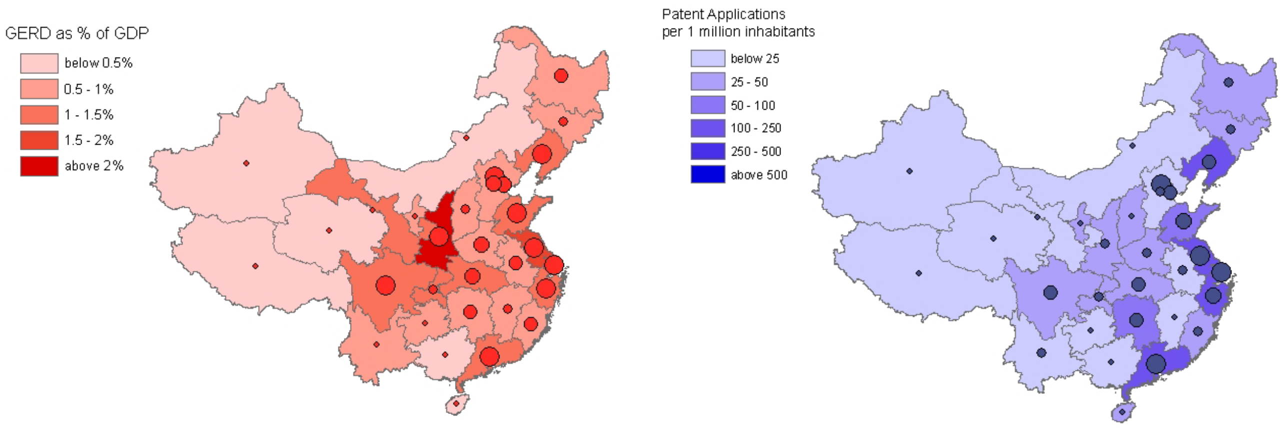


Source: SIPO, Fraunhofer ISI diagram

The Distribution of Scientific and Technological Activities in China

Somewhat against intuition, evidence thus shows that in China scientific and technological activities are more evenly distributed than overall wealth. A number of actors from the inland provinces have not yet entered the international stage in terms of patent applications and innovative exports, but do nevertheless generate significant regional research intensities (GERD as % of GDP) and apply for a noticeable number of patents at the Chinese national office. In this context, actors from Shaanxi, Sichuan, Chongqing, Hubei, Shandong, Liaoning and to a lesser degree Henan and Hunan have become noticeable 'second league players'.

Figure 5: Research Intensity and Patent Intensity in China



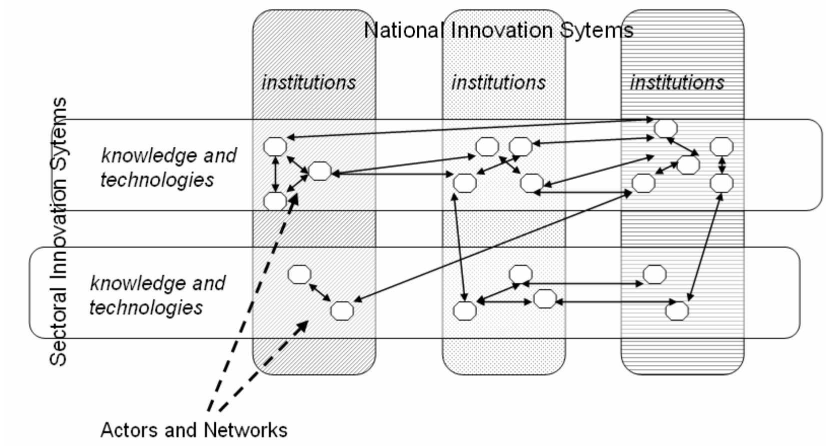
Source: sts.org.cn, China Statistical Office, Fraunhofer ISI calculations & cartography

Transforming and Upgrading Innovation Systems – Systems of Learning

Innovation theory suggests that for a region's innovating actors in a certain technological field, thriving regional innovation systems are localised interfaces in which they join and intersect interregional knowledge flows and organise their interregional knowledge exchange (Bunnel/Coe 2001). The re-combination of external and local knowledge assets through local learning is thus a process that is characteristic for any internationally open economic system.

Consequently, if the local public research landscape and other relevant firms are unfit to provide a suitable and sufficient supply of knowledge, local firms will source knowledge according to their needs – elsewhere. On the other hand, in regions in which the enterprise sector cannot absorb the knowledge supply provided by public research and higher education actors, knowledge will dissipate to other places where a sufficient demand exists.

Figure 6: Internationally Networked Regional Innovation Systems



Source: Fraunhofer ISI

Throughout the 'catching-up process' of an economy this continuous process of absorbing and locally adapting external knowledge is of particular importance (Lall 1992). While not all Chinese technological achievements can directly be traced back to external knowledge inflows, a more indirect 'inspirational' role of international knowledge flows can still not be denied in the majority of cases. The relative importance of international knowledge transfer remains of higher relative importance for China than for technologically leading countries.

Chinese S&T policy makers, however, have recently decided to increase their efforts to alleviate the external dependency of the national innovation system. A national conference on S&T was called in 2006 to provide the stage to launch a 'Medium- to Long-term S&T Strategic Plan (2006-2020)' setting the following strategic objectives (Cao et al. 2006):

- to build an innovation-based economy by fostering indigenous innovation,
- to foster an enterprise-centred technology innovation system,
- to achieve major breakthroughs in targeted areas of basic research & development.

In short, China aims to increase the capabilities of the domestic (public) research sector and make its activities more relevant for the enterprise sector to be able to increase science-industry collaboration on a broad scale.

Doubtlessly, this initiative comes at the right time even if during times of crisis. Theory suggests that when a country has upgraded its technological capabilities to a certain degree, international technology transfer can and should no longer serve as a substitute for domestic knowledge generation (Lall 2000), even if it has to continue to play a major role.

In the course of the past decades, China's domestic firms as well as the Chinese subsidiaries of multinational firms have developed an enormous absorptive capacity. They have proven masters with regard to sourcing international knowledge to upgrade local capability, and to adapt existing products and services to the needs of the Chinese market. Moreover, a growing body of literature illustrates that actors from the domestic high-tech(-park) industry, the top echelons of the domestic research sector (CAS etc.) and a limited number of foreign R&D centres have begun to form local systems of innovation characterised by rising interaction and fruitful collaboration which, in general, are carefully and consciously supported by central and regional governments.

These local systems, however, remain insular and insufficiently integrated with the rest of the economy. As pointed out above, despite substantial reforms, much of the domestic research sector does not yet provide an adequate offer for the industrial sector. Consequently, most of the current technological demand of the broader industrial sector continues to be satisfied through international knowledge transfer. For the time being, the Chinese innovation system remains characterised by fragmentation as well as a technological and organisational mismatch between its main domestic players.

In summary, it appears questionable, if foreign and domestic enterprises will in the nearer future turn to domestic institutes for technology transfer to an extent sufficient to provide a basis for the future national technological independence envisaged by the government.

In some particular cases such as in Beijing, Shanghai, and the Bohai region strong 'islands of innovation' exist so that foundations may already be laid for closer linkages between the scientific and the enterprise sector. In others such as in Guangzhou (and to a degree Shanghai) it appears a major task to change the existing culture of external knowledge sourcing relating both to the tapping of knowledge from multinational firm networks and the interregional tapping of human capital. For now, foreign industrial firms display little interest in local collaboration – as they have better options to source knowledge from abroad than other companies. This lack of inclination to co-operate locally (even among innovating enterprises) is evidenced by data on electronics firms in Guangdong as displayed in Table 1.

Table 1: Sources for innovation-related information of Guangdong electronics firms

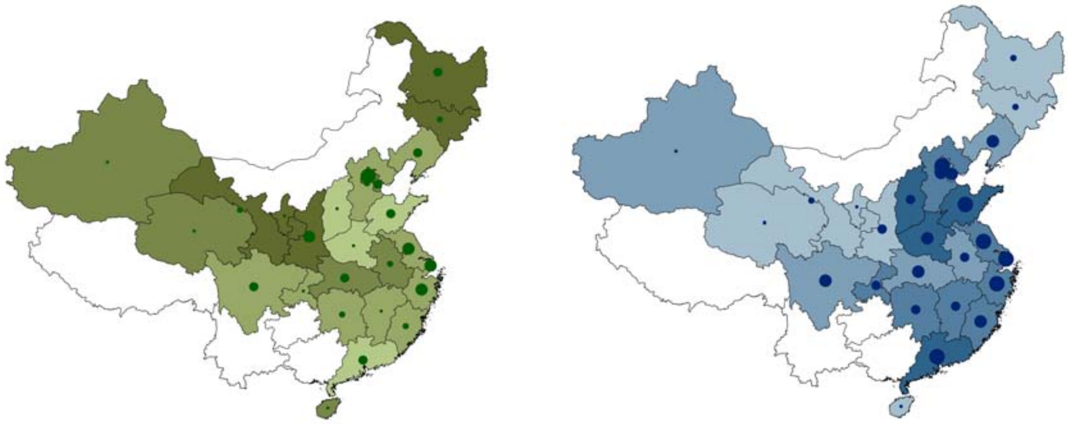
	all firms (n=156)	foreign firms (n=28)
hiring qualified workers	54%	50%
customer/supplier	45%	50%
parent/affiliated company	37%	64%
fairs/technical markets	31%	27%
other company	23%	27%
university/research institute	18%	14%

Source: Kroll/Schiller (2008)

Given the starting conditions, the establishment of a domestic nexus of technological cooperation and knowledge exchange as envisaged by the Chinese government appears to be an ambitious undertaking that will not evolve automatically. Currently, a dependence on international knowledge sourcing continues to make perfect economic sense for many industrial actors and will only be altered if attractive domestic substitutes become available. The question if and how the exploitation of local capabilities can be increased to reduce the external dependence of the national innovation system on a broader scale will thus become an important issue of the future decade.

Moreover, China's regional systems of innovation differ with regard to the overall structure of their S&T system (cf. Figure 7). Some regions remain characterised by a publicly dominated research system and culture. The most prominent examples of this are the provinces of Heilongjiang and Jilin in the old industrial centre of the north-east, the Bohai region with its state-owned firms and large national research facilities and Shaanxi with its large military-industrial complex. In many other regions, however, the situation is quite the opposite: Business expenditures on R&D dominate, while public research efforts are low to moderate. Besides the expectable case of Guangdong such a situation can also be found in northern inland provinces (Shanxi, Henan) and Shandong. Currently, the provinces of the Yangtze River Delta (Zhejiang, Jiangsu) seem to display the best mix of R&D investments as the Greater Shanghai area is home to diverse foreign-funded enterprise research facilities as well as public domestic research institutions.

Figure 7: Public and Enterprise Sector R&D Expenditure in China (shading: share)



Source: sts.org.cn, provincial yearbooks, Fraunhofer ISI estimations & cartography

The Match between Scientific and Technological Capabilities

Actors in an innovation system generate, transform, administer and distribute knowledge. To do so, they have to interact. In practice, there is a continuum of quite a number of different possibilities 'between market and hierarchy', most of which do at the baseline follow the logic of knowledge supply and demand, while they have to be enabled by administrative action, be it through legislation or the establishment of knowledge market intermediaries (more commonly know as technology transfer agencies). Beyond knowledge generation itself, the establishment of a match of knowledge supply and demand is thus one of the key tasks that need to be performed in a regional innovation system (Cooke/Leydesdorff 2004). In the current situation in which political will and economic necessity appear to remain set apart, national policies can at best encourage (or, pointlessly, force) R&D interactions, they cannot 'order' the exchange of knowledge and technology where there is no demand for the existing supply.

In this respect, two main issues are to be discussed: structural organisational challenges and technological mismatches between existing knowledge supply and demand. The first issue is of a mid- to long-term nature and has been discussed elsewhere (e.g. Kroll/Schiller 2008). Among the key reasons, why a sufficient and suitable supply of knowledge is not developed in the public research sector include, are:

- applied research and experimental development remain financed by government rather than the enterprise sector. Consequently, there is no need for the results to be practically relevant, which, in turn, they do not appear to be very often (public research institutions do not patent much),
- the higher education sector is an exception to this, having reached a degree of business orientation that is realised by few other countries. However, it has important other tasks to fulfil with regard to education and basic research so that any further business orientation may come at a price,
- support policies for the broader industrial sector do not sufficiently encourage interaction with the public research sector.

These questions are of great relevance for the future development of the Chinese innovation system as a whole and many regional innovation systems in Northern as well as in Southern China. However, they take a broad perspective which is mostly relevant for policy makers aiming to improve structures and framework conditions.

This paper, in contrast, aims to deal with the short term, bottom-up perspective. It aims to unveil in which regions of China technological enterprises could already now possibly find a match from the public research and the enterprise sector. By regional policy makers it could be read as information which competences still need to be built in a particular region to make it a potential centre of excellence in a certain field.

Measuring Matches

It is difficult to try to capture the notion of knowledge supply and knowledge demand by a simple set of indicators. This brief summary provides but a first overview that needs to be complemented and specified to allow conclusions about particular regional settings.

In a first step, knowledge supply will be measured through publication activity in a certain scientific field. Publication Counts were extracted and regionalised from the Elsevier Scopus database. Similarly, knowledge demand will be measured by patenting applications in a certain technological field, indicating the presence of relevant applied research activities. The necessary patent data was extracted and manually regionalised from the PATSTAT database. EPO figures were regionalised based on the address of the inventor, SIPO values, due to data quality, had to be assigned according to applicant.

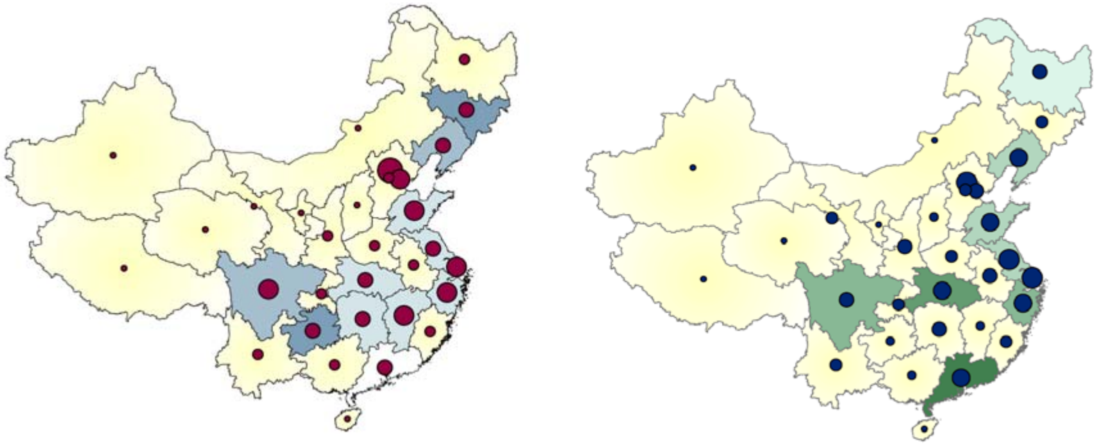
In both cases, a threefold approach to comprehensively characterise the overall regional situation will be taken as follows:

- The absolute degree of activity will be displayed (by a circle symbol), to illustrate if there is a critical mass of activity,
- The degree of specialisation will be displayed (by shading), to illustrate if the respective technology /field of science plays an above or below average role compared to the national average,
- For regions in which the activity amounts to less than 2.5% of national total specialisation will not be reported. A specialisation index indicating that 3 of 5 publications happen to be from chemistry has limited informative value and should not be displayed alongside one based on more than 200 publications.

As a result, maps of regional hot-spots have been developed for selected technological fields and related scientific fields. If the respective capacities and specialisations overlap in a region, it may have potential to develop a regional network of linkages, to become a cluster.

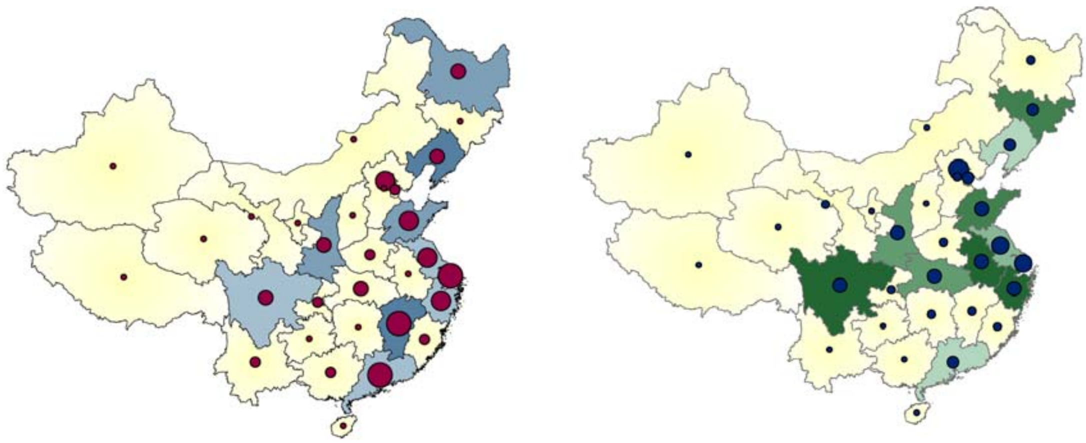
Easy-to-read as those maps are, it must be borne in mind that, logically, a one-to-one concordance between scientific fields and patent classes cannot exist. Hence, overlaps should be read as indications of relevant options rather than indications of definite possibilities for regional interaction.

Figure 8: Pharmaceutical Industry/Pharmacology – a good match



Source: Elsevier Scopus & Patstat Databases, Fraunhofer ISI calculation & cartography

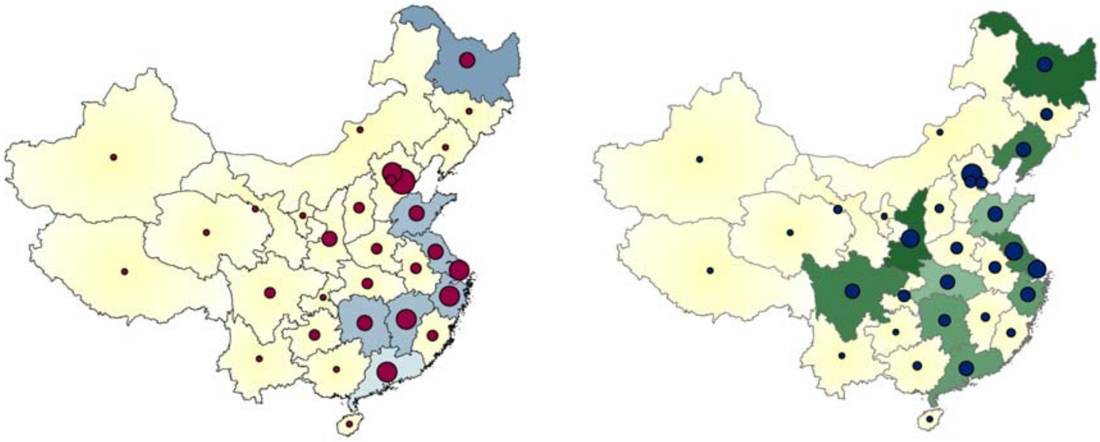
Figure 9: Optics / Physics – a moderately good match



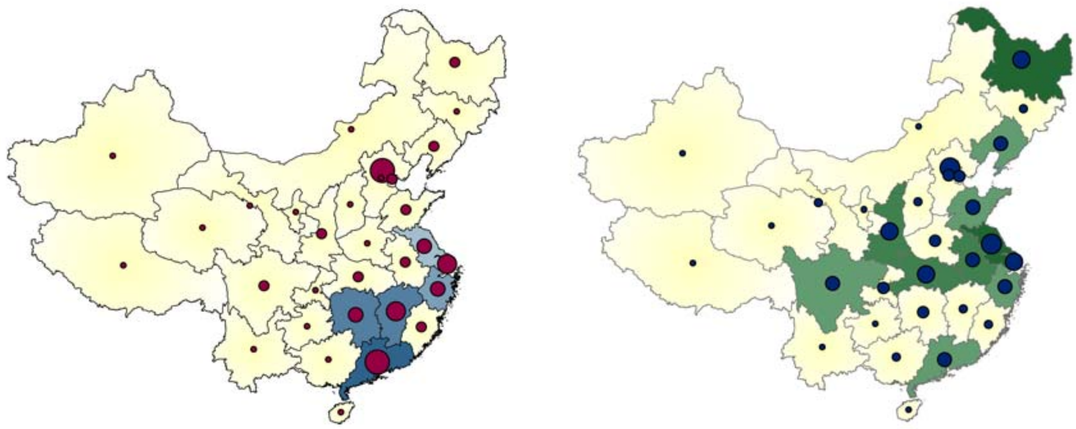
Source: Elsevier Scopus & Patstat Databases, Fraunhofer ISI calculation & cartography

Figure 10: Machine Building / IT and relevant Fields of Science – competences apart

General Machinery / Engineering

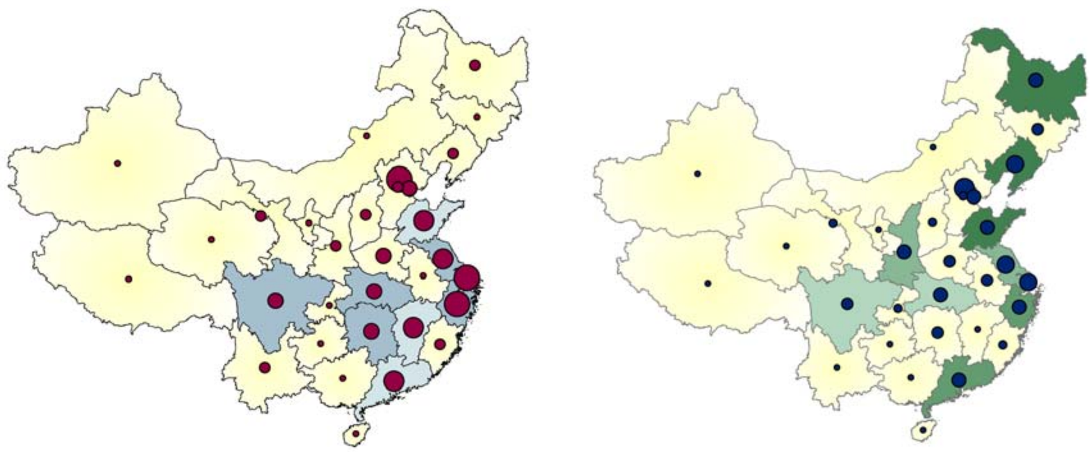


Computer Industry / Computer Science



Source: Elsevier Scopus & Patstat Databases, Fraunhofer ISI calculation & cartography

Figure 11: Basic Chemicals / Chemical Engineering – a moderately good match



Source: Elsevier Scopus & Patstat Databases, Fraunhofer ISI calculation & cartography

As the brief overview shows, the degree of regional overlap of academic and industrial capacities does indeed differ between technological fields.

- For some industries with a reasonably long history of development in China such as the pharmaceutical industry, a good regional overlap of scientific and technological capacities seems to exist.
- In other industries which draw on equally long-established scientific fields the regional match of scientific and technological activities is at least moderately good, even though some centres of industrial technological development seem to exist far from any relevant public research capacity.
- In the new, export oriented industries competences are set apart. While a high share of scientific work in engineering and computer science is performed in the public-based regional research systems of central China (Shaanxi, Sichuan) patenting in those fields is concentrated in the coastal provinces (except Fujian), Hunan and Jiangxi.
- In few provinces with high technological capabilities in a particular field (except Guangdong) is the degree of specialisation in this field very strong. To the contrary, overspecialisation is common in weaker regions.

In summary, this shows that in most cases and technological fields the search for cross-sectoral and inter-provincial complementarities merits consideration and may be essential to find suitable partners in research and development. Moreover, it suggests that even more than being technologically overspecialised many provinces will have structural weaknesses with regard to elements of the "innovative chain" within a certain technological field.

The author is fully aware that such a first, broad review of evidence is indicative. Just because competencies exist in parallel, the respective actors may – and in the majority of cases will – not co-operate. The might be specialised in separate sub-fields, they may be caught up in their respective institutional cultures – they might even be willing to interact but held back by external circumstances.

However, this is precisely the point this paper tries to make: a better knowledge about the scientific and technological potential in a certain regional environment enables actors assess which efforts are worthwhile and thus to better focus their networking activities. If it is known that there is significant academic potential nearby, it may be a worthwhile effort to commit resources to overcome organisational obstacles. If the potential is more evident in the local firm sector, efforts might be redirected.

Summary & Conclusions

The brief survey of scientific and technological strengths and weaknesses in the Chinese provinces has come to the following result:

- In many regions of China, a number of substantial thematic overlaps exist between scientific and technological capacities.
- If absorptive capacities in the industrial sector continue to rise and organisational issues in the public research sector are tackled, it is thus likely that the extent and level of regional knowledge exchange will increase outside the first tier cities.
- Equally clearly, a number of provinces display either only scientific or only technological capacities in a certain field. Those regions need to develop a strategy how to deal with this truncated specialisation.
- The same holds true with regard to the specialisation in terms of the sector of performance. To diversify, a build-up of public research capacities will be needed in regions with a so far mainly business dominated profile – if the officially proclaimed strategy of a business centred public research system is to be realised on a broader scale.
- The data indicate that the technological profiles of most provinces are focused enough not to waste resources on fields where a critical mass does not locally exist but diversified enough to reduce vulnerability to sectoral crisis. With regard to internationally visible technological activities, a stark concentration persists.
- Evidence thus suggests that, in the short run, companies will continue to locate close to the existing regional strengths in the first tier cities. Nonetheless, other possible locations are clearly emerging and will increasingly provide relevant opportunities in the coming years.
- A greater reliance on endogenous technology content will probably have to develop organically. At the current point in time, organisational ground-laying work has to be performed to ultimately arrive at the set objectives. In many regions, it appears too early to embark on initiatives to encourage local networking directly. Nonetheless, such initiatives may become an important complement to structural change.
- Whatever the perspective, a continuous monitoring of developments in relevant competing and emerging regions seems to be crucial to understand the local situation and not to miss shifting trends.

Overall it has become clear that any assessment of the local match of technological supply and demand and the resulting strengths, weaknesses, opportunities and threats of a location needs to be performed in detail and on a case to case basis. Only a detailed investigation can unveil all factors necessary to come to a well-founded solution.

Acknowledgement

I acknowledge the support of my colleague Nicolai Mallig who did not grow tired of implementing many iterations of database queries.

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Annex: A Case Study of Guangdong

Guangdong is a province in which R&D activities are very strongly dominated by the enterprise sector and within this sector by the electronics and telecommunication equipment industry. Its potential in the higher education and the public research sector have been very weak until the year 2000. Since then the government has embarked on a successful policy to, with the help of leading national universities, build and strengthen a local higher education sector and encourage the performance of industrially relevant R&D in that sector.

Table 2: Regional Expenditure on R&D in Chinese First Tier Cities (2005)

	Total (billion Yuan)	(share)		
		Independent Research Institutions	Large and Medium-Sized Enterprises (LME)*	Higher Education Institutions
China total	245.00	20.9%	51.0%	6.0%
Beijing	38.21	**47.6%**	10.4%	9.6%
Yangtze River Delta	64.15	13.8%	**58.6%**	9.5%
Guangdong	24.38	3.3%	**74.0%**	5.0%

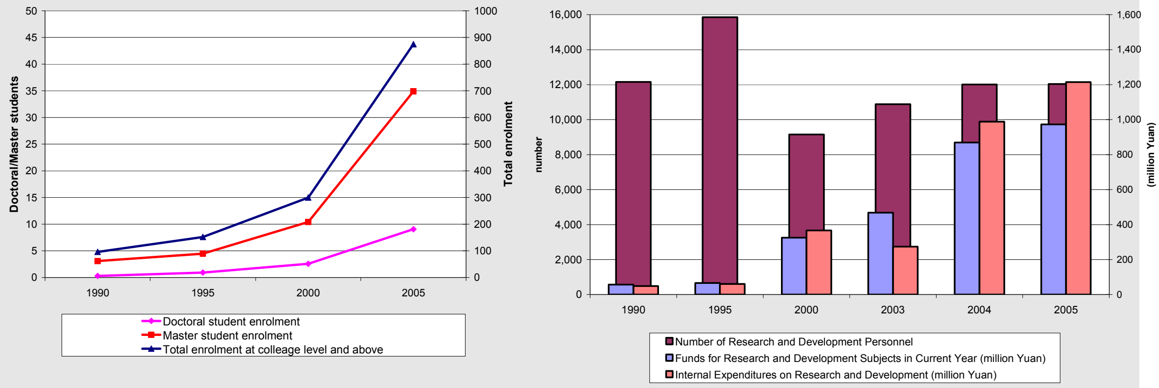
Source: China Statistical Yearbook of Science & Technology 2006

Table 3: Regional Expenditure on R&D by Industrial Branch in First Tier Cities (2005)

	Total (million Yuan)	Medical and Pharmaceutical Products Manufacturing	Aircraft and Spacecraft	Electronic and Telecommunication Equipment	Computer and Office Equipment Manufacturing	Medical Treatment Instrument and Meter Manufacturing
China total	36,250	11.0%	7.7%	64.7%	12.0%	4.6%
Beijing	2,072	6.6%	10.8%	43.5%	30.6%	8.5%
Yangtze River Delta	10,518	14.1%	0.5%	63.0%	15.1%	7.3%
Guangdong	**12,062**	**2.1%**	**0.2%**	**88.1%**	**7.5%**	**2.1%**

Source: China Statistical Yearbook on High Technology Industry 2006

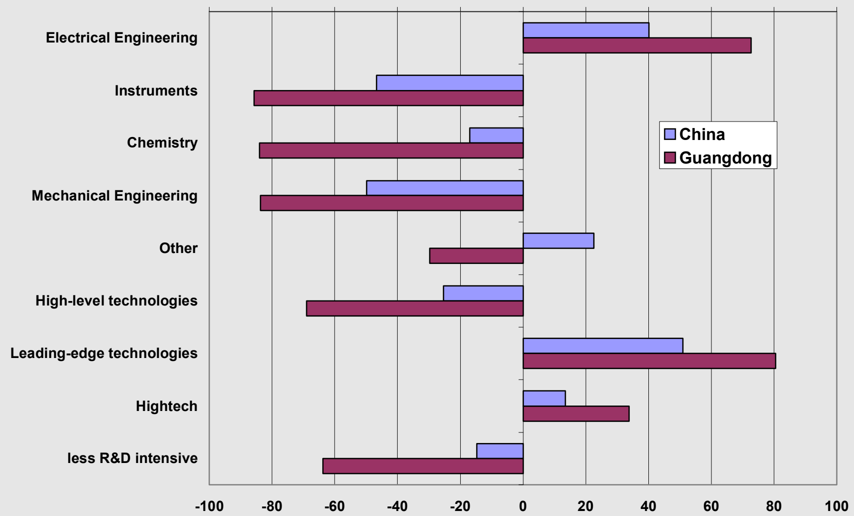
Figure 12: Development of Activities in the Guangdong Higher Education Sector



Source: Guangdong Statistical Yearbook, Guangdong Annual S&T Report, FhG ISI diagram

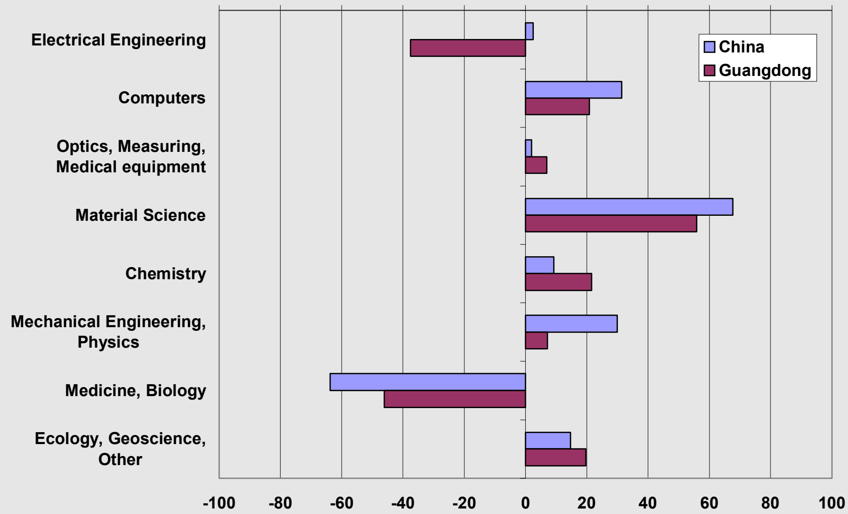
The profile of regional technological specialisation mirrors the specialisation in regional R&D expenditure. Guangdong is under-specialised with regard to all fields except electronic engineering. This profile however is not matched at all by the scientific specialisation where computer science and material science play the main role. Electrical engineering, in contrast, is not a focus so that, given the overall weakness of the public R&D sector in Guangdong, a significant support for the technological activities at the firm level does not seem to exist.

Figure 13: Profiles of Technological Specialisation of China and Guangdong, 2003-2005



Source: Patstat Database, Fraunhofer ISI calculations & diagram

Figure 14: Profiles of Scientific Specialisation of China and Guangdong, 2004-2006



Source: Elsevier Scopus Database, Fraunhofer ISI calculations & diagram

Conclusions

- Guangdong is in danger to lose its first mover advantage as the logic for the generation of wealth in China is about to change – other regions are endowed with better capacities needed for technological upgrading that may become the basis of future growth,
- The province's strong specialisation results in high vulnerability to sectoral crises and makes structural changes difficult to achieve,
- The openness of the Guangdong economy encourages external tapping of knowledge (and co-operation with partners from Hong Kong), providing a starting position that good that regional domestic providers of knowledge have difficulty to compete,
- Regional support policy is on the right track, but challenges are substantial.

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