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Exploring Pathways of Regional Technological Development in China through Patent Analysis

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Contents Page

1 Introduction 1

2 Conceptual Approach..2

3 Methodology...6

4 Findings 7

4.1 Level of Activity 7

4.2 Role of Regional Actors (Public vs. Private)..................................9

4.2.1 Technological Specialisation and Sectoral Focus 11

4.2.2 Outward Orientation / International Relevance of Patenting...15

4.2.3 A Classification of Chinese Regions’ Technological Systems 18

4.2.3.1 Technological Systems' Characteristics and Technological Growth 21

5 Discussion...26

6 Conclusions 28

7 References...29

Tables

Table 1: Patterns of regional concentration and de-concentration in Chinese regional patenting 15

Table 2: Characteristics of the six clusters 21

Table 3: Stepwise model identifying correlations between application structure and growth 23

Table 4: Growth of SIPO patent applications differentiated by period and cluster 24

Figures

Figure 1: Growth in patent applications in Chinese provinces 2008-2013 8

Figure 2: Patterns of patent application in Chinese provinces (patent intensity and growth) 9

Figure 3: Patterns of university patent applications in Chinese provinces 10

Figure 4: Regional concentration and specialisation of Chinese patent applications in the field of telecommunications (absolute number and location quotient)............................... 12

Figure 5: Regional concentration and specialisation of Chinese patent applications in the field of general machinery (absolute number and location quotient)............................... 12

Figure 6: Regional concentration and specialisation of Chinese patent applications in the field of pharmaceuticals (absolute number and location quotient)............................... 13

Figure 7: Share and number of SIPO patents transferred to WIPO via PCT (2012)... 16

Figure 8: Share and number of SIPO patents to WIPO via PCT (2008) 17

Figure 9: Share and number of SIPO patents with family members at the Taiwanese patent office.............................. 17

Figure 10: Classification of provincial technological systems into four clusters 19

Figure 11: Classification of provincial technological systems into six clusters 19

Figure 12: Growth of SIPO patent applications differentiated by period and cluster (diagram) 25

Figure Annex 1: Regional distribution of applications in the field of electrical machinery 32

Figure Annex 2: Regional distribution of applications in the field of electronic components 32

Figure Annex 3: Regional distribution of applications in the field of telecommunications 33

Figure Annex 4: Regional distribution of applications in the field of audio-visual electronics 33

Figure Annex 5: Regional distribution of applications in the field of computers 34

Figure Annex 6: Regional distribution of applications in the field of measurement and control 34

Figure Annex 7: Regional distribution of applications in the field of medical equipment 35

Figure Annex 8: Regional distribution of applications in the field of optics 35

Figure Annex 9: Regional distribution of applications in the field of basic chemicals / petroleum 36

Figure Annex 10: Regional distribution of applications in the field of polymers, rubber and fibres 36

Figure Annex 11: Regional distribution of applications in the field of non-polymer materials 37

Figure Annex 12: Regional distribution of applications in the field of pharmaceuticals 37

Figure Annex 13: Regional distribution of applications in the field of energy machinery 38

Figure Annex 14: Regional distribution of applications in the field of general machinery 38

Figure Annex 15: Regional distribution of applications in the field of machine tools 39

Figure Annex 16: Regional distribution of applications in the field of special machinery 39

Figure Annex 17: Regional distribution of applications in the field of transport 40

Figure Annex 18: Regional distribution of applications in the field of metal products 40

Figure Annex 19: Regional distribution of applications in textiles, paper, dom. appliances, food etc. 41

Figure Annex 20: Classification of provincial technological systems into eight clusters 41

1 Introduction

Over the course of the past two decades, China has evolved from a nation focused on production to a technologically dynamic one with the ambition to catch up with the world's leading economies by 2050 (Schwaag Serger and Breidne 2007; State Council (of the People's Republic of China) 2006). Since 2011, it has become the nation with largest annual patent output in the world (Reuters 2011). At the same time, however, China also remains a huge country in which substantive disparities continue to prevail (Kroll 2010; Liefner and Wei 2013). For a long time, talking about new technological trends and growing capacity in China was almost identical to talking about new developments in Beijing, Guangdong, and Greater Shanghai. At the same time, this meant talking about two separate research systems, a public and an industrial one that were distinct, not only in terms of their legacy and internal logics (Motohashi 2008), but also in terms of their geographical representation (Kroll and Frietsch 2014; Kroll and Schiller 2010). As a result, meaningful knowledge transfer between these two systems only occurred in a limited number of 'islands of innovation', where regionally unique systems of co-operation had developed over the years (Kroll and Liefner 2008; Kroll and Schiller 2010).

Five years ago, Fraunhofer ISI conducted a first study on the regional distribution of research and innovation activities in China relying on data available up to 2008 (Kroll 2010). This study delivered a snapshot of a Chinese economy, in which both public research and technological development in various industries had begun to play a substantial role while, by and large, the above mentioned statements concerning the strong regional concentration of R&D activities still applied. In the meantime, however, anecdotal evidence suggests that this picture has changed (Kroll and Schnabl 2014). More and more often, it is being suggested that technologically advanced industries are moving further inland while more and more regional innovation systems are developing outside the classic 'islands of innovation' (Kroll and Frietsch 2015). In parallel, an increasing number of central and local government policies are pushing 'self-sufficient' or 'indigenous' innovation, as well as the need to improve meaningful science-industry collaboration. At the very least, this push has induced substantial efforts to bridge the gap between the public and the private sector (Cao et al. 2009; Liu and Lundin 2009; Schwaag Serger and Breidne 2007). Alongside these new trends, the old centres of Beijing, Greater Shanghai and Guangdong are continuing to develop very dynamically (Kroll and Frietsch 2014; Tagscherer et al. 2012).

Given this background, it seems apt to review some of our 2010 findings and use patent analysis to determine whether some of these new trends have indeed prompted visible changes in Chinese provinces' patterns of technological activity, local collaboration and international orientation.

2 Conceptual Approach

As many prior studies have shown, innovation systems that are undergoing a process of transformation tend to be characterised by strong dependence on external, international knowledge. In China's provinces, a broad base of foreign-invested technology firms built up over the past three decades has developed a framework for external knowledge adaptation and processing that differs markedly from that of most Western countries (Liefner 2006; Liefner and Wei 2011; Sun 2003; Sun et al. 2013). At the same time, China also harbours substantial capacities in its diverse domestic public research sector (Kroll and Frietsch 2014; Kroll and Schiller 2010). While, with a view to the first aspect, it thus still displays some structures similar to those in developing nations, it could not differ more markedly with regard to the second (Kroll and Liefner 2008). For quite some time now, China has overcome its formerly almost exclusive dependence on external knowledge inflows and its government is eager to support and promote any opportunity for “indigenous innovation”, i.e. new developments based on domestic sources of technology (Kroll and Schiller 2014; Kroll and Tagscherer 2009; State Council (of the People's Republic of China) 2006; Wei and Liefner 2012).

Additionally, the industrial structure of transforming innovation systems like China's used to be characterised by a range of major players in the state-owned sector, foreign-invested firms, and, on the other hand, a quite limited number of strong players in the private sector (Kroll 2011; Kroll and Frietsch 2014). While state-owned firms often prevail in traditional, mature industries, private and foreign-invested enterprises have come to dominate in modern sectors like IT or telecommunications. Although this dichotomy may no longer be as clear cut as it used to be, it continues to fuel diverging logics of development in different industries and technological fields (Kroll and Schiller 2012; Schiller and Kroll 2013). As different types of firms are exposed to domestic and global trends to a different degree (Liefner et al. 2012; Wei et al. 2011), the different industries' distinct institutional composition produces different internal logics of development. This is likely to produce varying localisation patterns to a stronger extent than in Western economies, where sectoral differences in development are often mostly driven by technology rather than institutionally (Dosi 1988; Schmoch et al. 2003).

Furthermore, recent figures on patent activities and financial investment in enterprise sector research and development suggest that a transformation may be imminent from technology absorption and adaptation to genuine creation of new, world market-relevant innovations in domestic firms. Contrary to the past when such innovations were mostly limited to single firms in specific regions, like Huawei or ZTE (Kroll 2011; Kroll and Schiller 2012), a broader basis of internationally-relevant technological capacities may be emerging. At the same time, it remains unclear to what extent current patenting is actually the result of new technological capacities or whether it is being triggered by political encouragement or pressure to increase the number of domestic applications regardless of their quality (Li 2012; Prud'homme 2012) – in order to create the appearance of 'indigenous' innovation.

Finally, China, like all other countries, is exposed to international technological trends that its industries have to respond to (Sun et al. 2013). While these trends drive long-term transformations and change the positioning of regions vis-a-vis each other, they also create the short-term framework for different provinces' growth perspectives and resilience in the face of specific sectors' cyclical crises (Schiller and Kroll 2013). In concert with the abovementioned national trends, this international framework will codetermine the extent to which specific locations will be able to strengthen and maintain their position in the overall national system of technological production or, in the case of followers, catch up with the established leaders.

Hence, there are four relevant structural characteristics of regional innovation systems that can be analysed by means of patent analysis are the following:

Firstly, the *overall level of technological activity*. Technological activities developed earlier and faster in some of China's provinces than in others. For that reason alone, some provinces have a better chance to develop the critical mass needed to create functioning regional innovation systems or improve existing ones. In the past two decades, moreover, a high level of pre-existing technological activity was more or less synonymous with the local occurrence of technology transfer islands or clusters of internationally competitive firms. In short, capturing the overall level of technological activity is relevant to assessing a regional system's capacity to create or enhance mutually reinforcing dynamics at a local level.

Secondly, the *relative role of the public and the private sector in patenting*. Beyond the mere scale of the technological activity, this measure captures the potential for local complementarities between pre-competitive, applied research and concrete, market-oriented technological development. Whereas a certain overall level of technological activity is a necessary condition to enable mutually reinforcing dynamics, the foundation for genuinely self-supporting regional innovation systems can only be laid if there is sufficient critical mass in both the public and the private sector. While a sufficient level of market-orientation is needed to development, R&D capacities in the public sector may be needed to connect regions to different international networks.

Thirdly, *technological specialisation and sectoral focus*. Firstly, different sectors are subject to different global trends. Some fields, like information technology or telecommunications, are modern industries with short cycles, while others, like general machine building or chemistry are more mature and characterised by longer cycles. Secondly, technological specialisation and focus can be read in the Chinese context as a proxy for the internal structure of the patenting enterprise sector that dominates the regional innovation system. While some sectors are characterised by large, state-owned firms that are more prone to respond to political targets, others are characterised by private players targeting international markets.

Finally, *outward orientation, i.e. patent family members abroad.* Even today, this measure remains crucial, not only to retrace the home market orientation of foreign-invested firms, but also as a proxy for the relevance of the patents applied for with regard to an overall 'new to the world' benchmark. While patent applications at SIPO may be politically triggered, few Chinese firms will take the trouble to file at international offices for mere political reasons, let alone succeed. While this holds in principle, the occurrence of family members at the World Intellectual Property Office is likely to provide more reliable information of quality than that those at specific, foreign, home market-oriented ones such as the Korean or the Taiwanese offices.

As prior studies have shown, moreover, there is no longer a clear cut differentiation between “the coastal” and “the inland” provinces, “the north” and “the south”, or any other official classification that would be intuitively useful to meaningfully analyse the spatial dynamics of technological development in the Chinese innovation system. Consequently, a research gap exists not only with a view to the disparities and patterns of the above mentioned aspects themselves, but also with respect to a meaningful method of condensing this information into an overall classification which could help structure further analysis.

In summary, China's regional technological systems are likely to display different structures to varying dimensions that form the foundation for their potential to change the spatial balance in the national innovation system. This paper aims to analyse these differentiations, carve out differences in regional profiles, and develop an overarching characterisation of regional innovation systems based on patent data. Finally, it will analyse to what extent the regionally-specific growth of patent applications in the overall system can be better understood with a view to the currently prevailing differences in structure.

Against this background, the following four hypotheses can be put forward:

H1: While China's current technological system continues to create a win-win situation for its strong regions, new sectoral, technological and political trends will prompt a capacity-based catch-up in particular provinces.

H2: In parallel to the emergence of new, general trends at both the global and the domestic level, there will have been some noticeable changes to the structural composition of the technological systems in China’s provinces.

H3: While China's provinces display quite distinct profiles with respect to their technological activities, these are not completely idiosyncratic but can be subsumed under a number of meaningful, more general categories.

H4: Recent growth in technological activities in Chinese provinces will depend on the respective province’s technological profile to a significant extent. Hence, there will likely be differences between analysing the system as a whole and the parts engaged in technology catch-up.

The following section presents the methodology of data generation, treatment and analysis in more detail. Subsequently, findings and patterns with a view to the different analytical perspectives are documented. Finally, these findings and their implications are discussed and conclusions drawn.

3 Methodology

Other than the preceding 2010 study, this paper draws exclusively on a differentiated analysis of patent applications. To confirm or refute the hypotheses stated above, it appears most promising to analyse the results of technological activities rather than the input to them.

Furthermore, a study focusing on developments *within* China has to take the Chinese market as its main point of reference. Consequently, all patent applications analysed in this study are those made at the Chinese State Intellectual Property Office (SIPO) unless otherwise stated. In principle, these data are easily accessible and can be transferred into international patent databases with a sufficient level of reliability. Nonetheless, conducting a study with the objectives outlined above remains a challenging undertaking for a number of reasons.

Firstly, the detailed information on a specific patent's attributes needed to conduct an analysis of the type of applicant, international orientation and technological content is currently not directly available in any usable format from Chinese sources. Fortunately, however, it can be retrieved from a full (and specifically further developed) version of the EPO's Worldwide Patent Statistical Database (PATSTAT).

Secondly, information on the region in which the patent application took place cannot be retrieved from PATSTAT in the usual manner since Chinese patent documents are structured somewhat differently from the international standard at other offices. In particular, they do not contain accessible address information for individual applicants or inventors. Fortunately, however, some information on the place of application is included in SIPO raw data.

Thirdly, substantial data processing is needed to arrive at meaningful classifications of technological fields, organisational types and to identify SIPO patents which have a family member abroad. Fortunately, Fraunhofer ISI can draw on a considerable history of prior work in these fields and was able to apply already established and proven approaches in this study.

Consequently, the first and most crucial step towards creating a suitable database for the analysis was to merge specific information from Chinese raw data with the full and treated version of EPO PATSTAT that Fraunhofer ISI uses in-house. The required data concerning each Chinese patent's place of application was contributed directly by the Chinese National Library of Sciences, drawing on SIPO sources. On that basis, reliable indicators for the three aforementioned structural dimensions could be constructed as follows.

The *relative role of the public sector* in patenting could be determined based on text search routines that identify applicants as pertaining to either the public research sector (university, public research institute) or the private economic sector (firms, individual inventors). Overall, these routines are proven and can be assumed to work well in China. Confirmatory checks of individual cases did not reveal any evidence to the contrary.

The *technological field* to which a specific patent relates can be determined based on its IPC codes assigned according to a tried and tested list of overarching technological fields, the so-called ISI-19 list. This classification has been used in multiple studies throughout the past decade and provides a reliable point of reference. Moreover, it differentiates clearly into (as such) more modern and more traditional fields.

The *outward orientation and/or international relevance* of specific patents can be proxied by whether or not they have patent family members at other offices, i.e. whether attempts have been made to protect the invention in question not only on the Chinese market but on other international markets as well. Furthermore, international family members can be differentiated by the specific non-Chinese office where they are filed, to capture the different aspects mentioned above.

These were used to conduct a detailed patent analysis as outlined above.

4 Findings

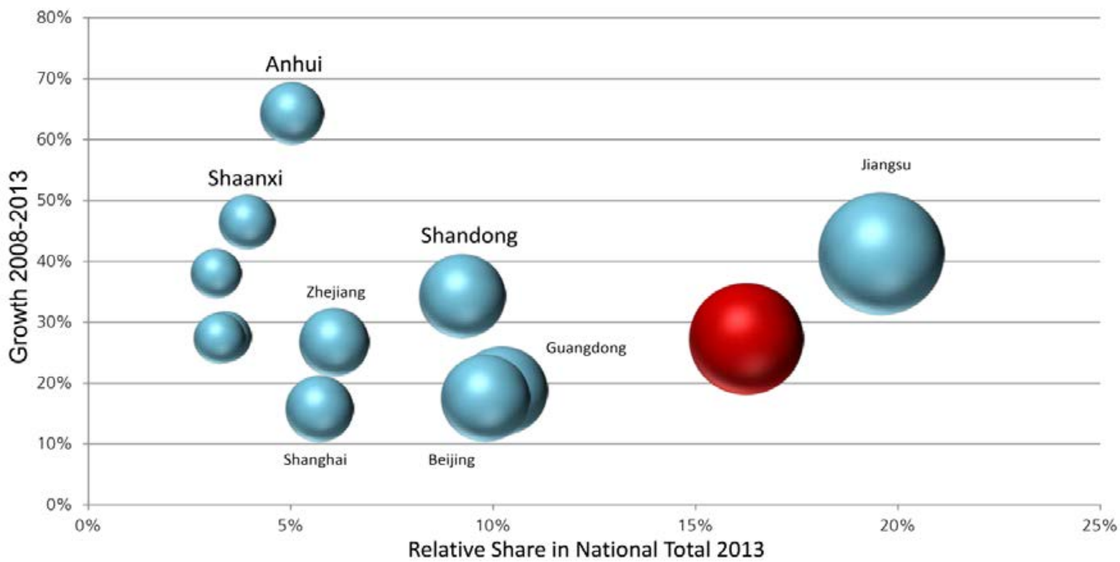
This section presents the study's empirical findings along the four main dimensions of analysis (addressing Hypotheses 1 and 2) and then moves on to present the results of further analyses needed to address Hypotheses 3 and 4.

4.1 Level of Activity

With a view to Hypothesis 1, it can be observed that the number of patent applications in China's leading technological regions is still increasing substantially at a rate of around 20%. Nonetheless, these regions are increasingly outperformed by other provinces ranked among the nation's top ten regions (Figure 1). More specifically, for example, Anhui's annual patent output has increased by more than 60% since 2008, while Shaanxi's has grown by close to 50% and Shandong's by around 35%. The number of patent applications in all the remaining provinces taken together (red sphere in figure) displays an above average growth rate as well.

In summary, these most recent data suggest that a gradual, yet continuous catching-up process is underway outside the country's former leading technological centres. One notable exception is the province of Jiangsu in the Greater Shanghai area, where technological activities continue to grow at an above average rate, even though the region is already ranked first nationally and accounts for close to 20% of China's overall patent output. In a sense, a double trend with regard to overall disparities can be observed. At the national level, Jiangsu's forging ahead is likely to increase the overall level of regional inequality, because of the region's substantial influence. At the same time, this effect will be compensated by the overall mitigation of disparities caused by the generally more convergent development among all the other provinces.

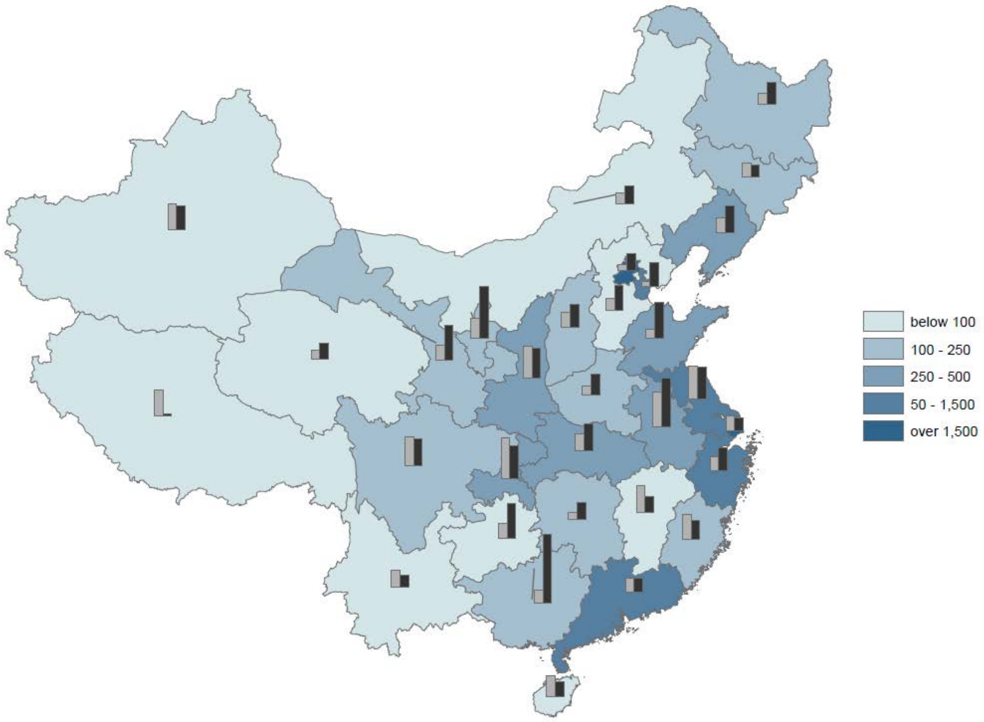
Figure 1: Growth in patent applications in Chinese provinces 2008-2013



Note: Size of spheres equals absolute number of patent applications
Source: Own analysis

As Figure 2 clearly illustrates, the traditional pattern of technological activity in China has thus not been substantially reversed. Evidently, the division into strong coastal areas, China's increasingly active geographical centre and a number of largely detached peripheral regions still seems to hold. Figure 2 also shows that many inland provinces display growth rates that exceed those in established coastal areas. In line with the patterns found in Figure 1, these differences in growth rates seem to have been enhanced in recent years (columns indicating growth 2008-2010 vs. growth 2010-12).

Figure 2: Patterns of patent application in Chinese provinces (patent intensity and growth)



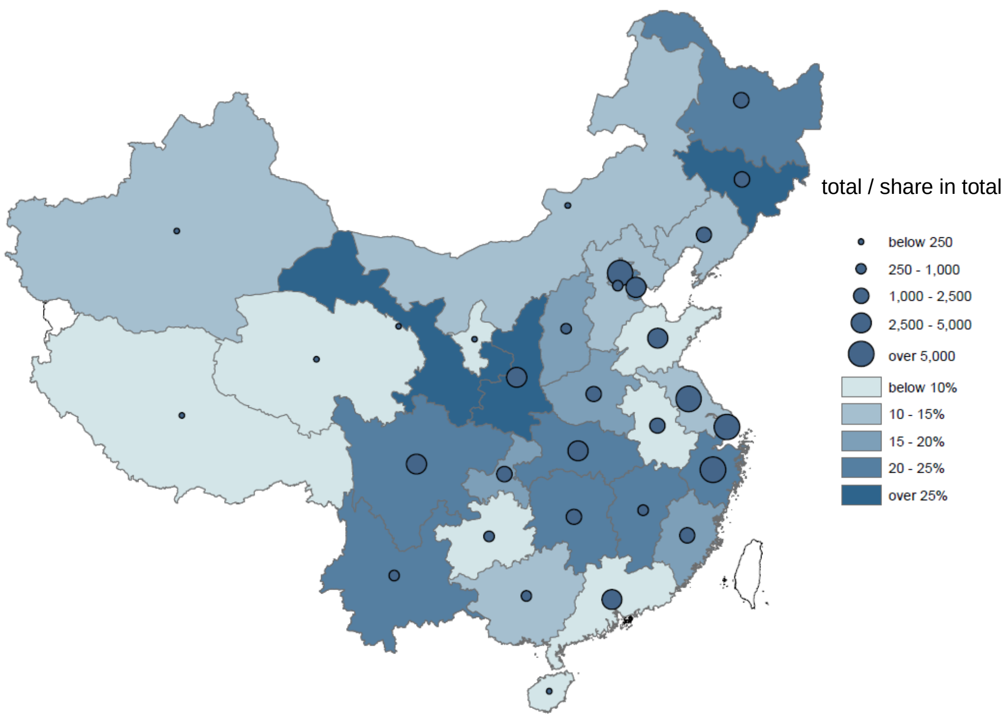
Note: Grey and black columns indicate growth from 2008-10 and from 2010-12, respectively
Source: Own analysis, map based on ESRI ArcGIS

4.2 Role of Regional Actors (Public vs. Private)

In a first step towards addressing Hypothesis 2, this study finds that the role and relative importance of applicants from universities differs notably between Chinese provinces. In general terms, the observed patterns remain in line with those found in earlier years. Nonetheless, the regional distribution of university patenting in China has experienced a stronger degree of de-concentration than patenting in general. While the overall Gini coefficient has barely changed from 62.67 in 2008 to 61.06 in 2012 (probably due to the strong role of Jiangsu), the degree of concentration with respect to university patents has decreased substantially from 61.15 (2008) to 56.96 (2012). Apparently, there is a trend at work here that is less relevant for the overall innovation system, i.e. the overall economy.

Furthermore, it is worth noting that a high share of university patenting cannot be considered an attribute of either leading or lagging regions. Cases of a strong role of the public research sector can be found equally among leading (Zhejiang) regions, catching-up (Sichuan) or lagging behind (Gansu) regions. Likewise, university patenting can play a limited role in all three types of regions (Guangdong, Anhui, Tibet). Consequently, the role of universities in regional patenting can be interpreted as a general and largely independent characteristic of a regional technological system that neither predetermines the system's success or failure nor provides evidence for a province's success or failure. Instead, it documents one specific characteristic of a local technological system that illustrates whether a region is likely to be receptive to (domestic) trends in the public research sector. One example of such a trend is the setting of political targets to increase the output of patents or new stipulations that make patenting a prerequisite for promotions.

Figure 3: Patterns of university patent applications in Chinese provinces



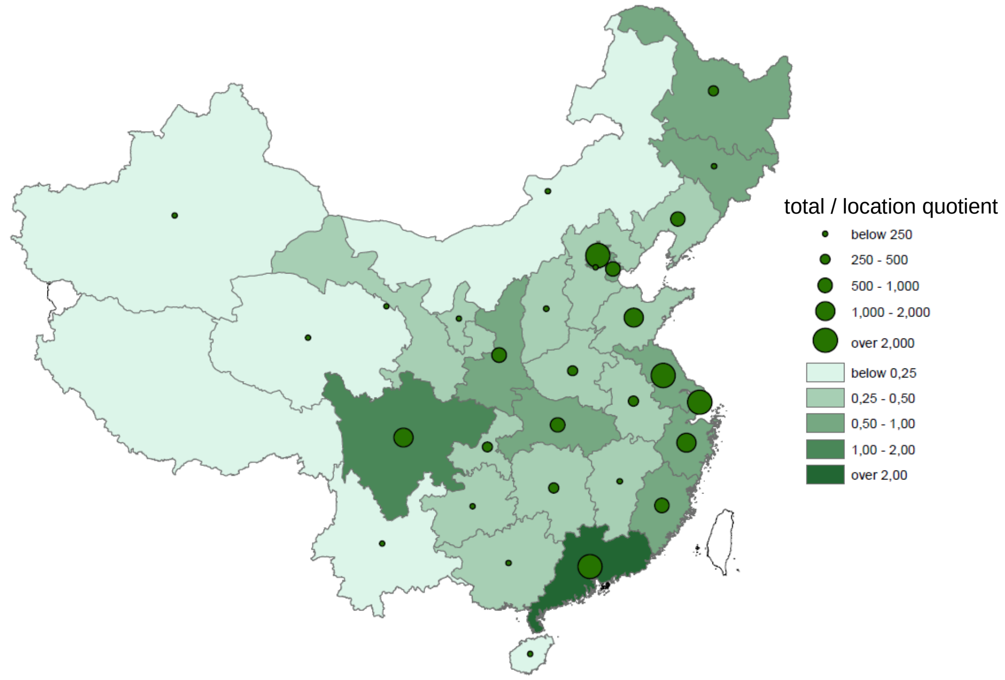
Source: Own analysis, map based on ESRI ArcGIS

4.2.1 Technological Specialisation and Sectoral Focus

In the second step to address Hypothesis 2, the analysis reveals a mixed picture with respect to technological specialisation. As a tendency, regional disparities tend to be higher in those technological fields in which China is a relevant world market-oriented player and in which foreign-invested and or large private activities contribute the dominant share of patent applications. In contrast, regional disparities tend to be notably less pronounced in fields related to mature sectors producing for the domestic market, and in which state-owned firms still contribute the largest share of all technological activity.

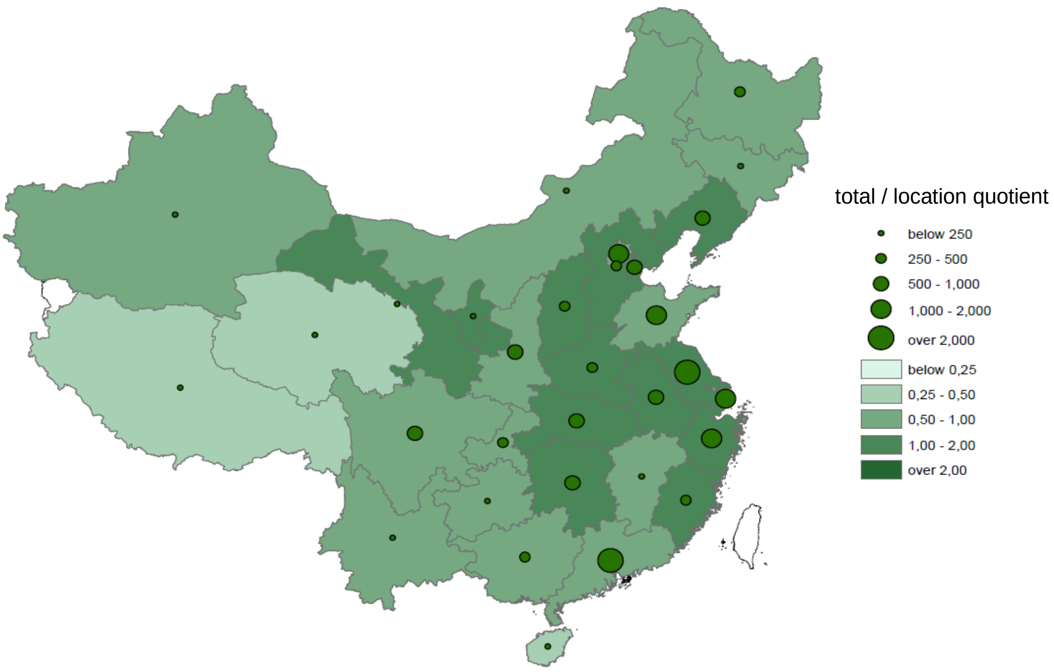
To illustrate this concept, Figure 4, Figure 5, and Figure 6 present three examples of regional patterns in specific technological fields (further examples in Annex). Figure 4 illustrates the distribution of patent activities in the field of telecommunications, in which activities remain strongly concentrated on Beijing, Guangdong and a few other coastal provinces. The telecommunications sector currently displays the strongest regional concentration among all fields. In both absolute and relative terms, it remains concentrated on leading regions. Figure 5 illustrates the regional distribution of applications in the field of general machinery, which still displays notable disparities but by no means as strong as in the field of telecommunications. While, in absolute terms, most activities are still concentrated along the coastline, in relative terms (specialisation), general machinery is a significant area of activity in a number of inland provinces. Figure 6 illustrates the regional distribution of applications in the pharmaceutical field. This field is characterised by domestic companies, many of them state-owned, and certainly mostly oriented towards the home market. Looking at the map, it seems that high specialisation in this field is indeed tantamount to an indicator of technological backwardness (even if the probable special effects of 'Traditional Tibetan Medicine' are taken out of the equation). Hence, technological activities in the pharmaceutical sector have the lowest regional concentration among all fields.

Figure 4: Regional concentration and specialisation of Chinese patent applications in the field of telecommunications (absolute number and location quotient)



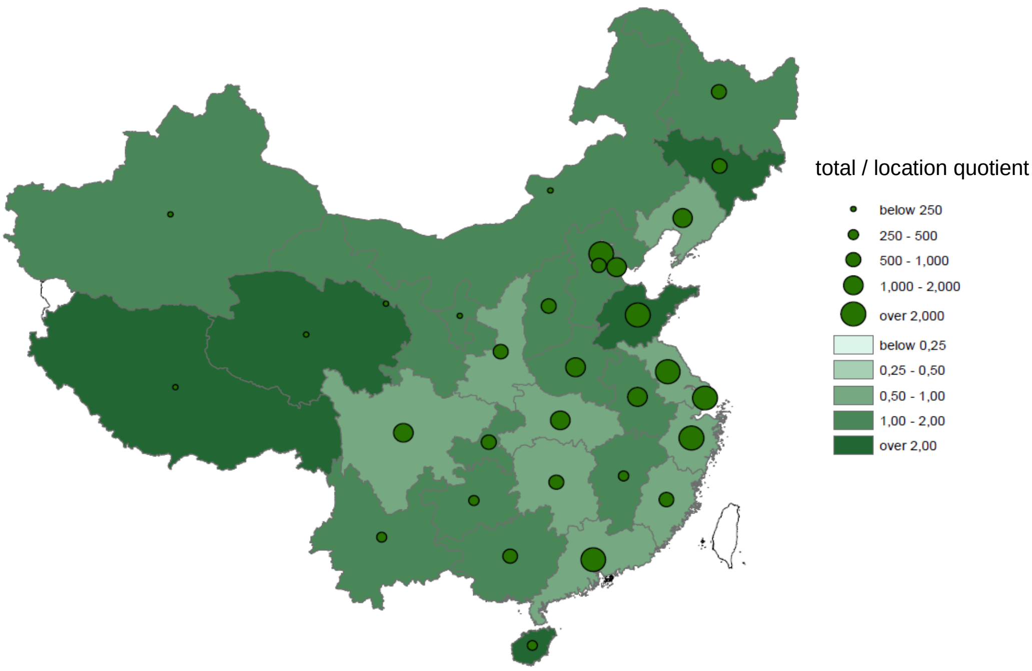
Note: Location quotient indicates *specialisation*, i.e. share in regional total / share in national total
Source: Own analysis, map based on ESRI ArcGIS

Figure 5: Regional concentration and specialisation of Chinese patent applications in the field of general machinery (absolute number and location quotient)



Note: Location quotient indicates specialisation, i.e. share in regional total / share in national total
Source: Own analysis, map based on ESRI ArcGIS

Figure 6: Regional concentration and specialisation of Chinese patent applications in the field of pharmaceuticals (absolute number and location quotient)



Note: Location quotient indicates specialisation, i.e. share in regional total / share in national total
Source: Own analysis, map based on ESRI ArcGIS

While the share technological activities that is performed in the public sector makes a region responsive to certain types of policies, its specialisation in one technological field or another makes it more receptive to certain global technological (or sectoral) trends. Moreover, mostly state-owned industries may be subject to other aspects of industrial support policies than largely privately and/or foreign-owned sectors. Finally, different industrial sectors will respond differently to changes in the availability of specialist human capital or overall labour cost changes. While some firms may choose to re-locate inland, others may choose to concentrate around specialist clusters or universities that provide specialist knowledge and graduates.

Consequently, this paper undertakes not only an analysis of the current status quo, but also one of recent (2008-2013) changes with regard to the regional concentration of activities in different technological fields. While such an analysis cannot identify the precise reasons for specific trends in individual sectors, it can try to capture the underlying logic of change through a comparison of sector-specific development.

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In summary, the analysis illustrated in Table 1 finds that modern, internationally-oriented, and largely private-dominated sectors tend to display a notable tendency towards de-concentration. Examples include telecommunications, audio-visual electronics and electrical machinery. On the other hand, inventive activity in more traditional, generic fields such as metal products, non-polymer materials, machine-tools, and others (textiles etc.) displays a slight tendency towards concentration. While the exact reasons for these tendencies remain unknown, Table 1 indicates that some capacities in 'modern' industries are moving further inland and that activities are expanding beyond the formerly small group of key applicants from Guangdong. At the same time, we may be observing a process of regional clustering in more traditional industries as they undergo internal modernisation and become more dependent on specific regional sources and pools of knowledge.

Maps showing the regional distribution of patent application activities in other technological fields are included in the Annex.

Table 1: Patterns of regional concentration and de-concentration in Chinese regional patenting

	2012	2008	
Telecommunications	76.02	82.62	-6.60
Audio-visual electronics	77.39	83.38	-5.99
Electrical machinery, apparatus, energy	65.93	69.63	-3.70
Measurement, control	60.61	64.01	-3.40
Optics	69.04	72.35	-3.31
Pharmaceuticals	55.29	58.35	-3.06
Computers, office machinery	75.14	78.19	-3.05
Basic chemicals, paints, soaps, petroleum products	56.36	58.77	-2.41
Electronic components	72.22	73.84	-1.62
Medical equipment	62.32	63.46	-1.14
Transport	57.17	57.77	-0.60
Special machinery	58.92	59.29	-0.37
General machinery	62.95	62.27	0.68
Polymers, rubber, man-made fibres	64.28	63.4	0.88
Metal products	62.37	61.46	0.91
Non-polymer materials	56.98	55.61	1.37
Energy machinery	62.14	60.74	1.40
Textiles, paper, domestic appliances, food etc.	58.92	56.68	2.24
Machine-tools	64.41	61.71	2.70
TOTAL	**61.06**	**62.67**	**-1.61**

Source: Own analysis

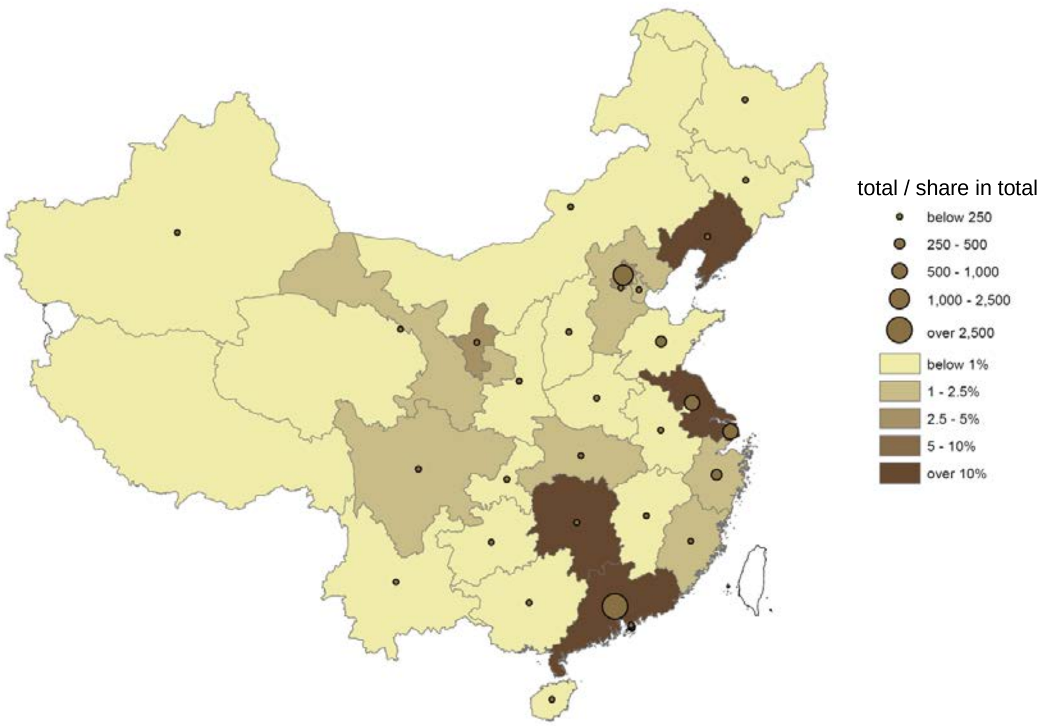
4.2.2 Outward Orientation / International Relevance of Patenting

In the third and final step towards addressing Hypothesis 2, this study analysed the international relevance of patent application at the SIPO. In this regard, it finds that Chinese patent applications which are considered sufficiently relevant to the world or other international markets to also file them at other offices or transfer them through the Patent Cooperation Treaty (PCT) have always produced by a much smaller group of leading institutions and, as a result, been geographically much more concentrated than technological activities in general. The basis for this concentration throughout the past decade is that most firms and research institutions with international orientation and strong technological capacities are located in the three main areas of Beijing, Guangdong, and Greater Shanghai.

In 2012, the Gini coefficient of the regional distribution of WIPO transferred patents was 82.68 compared to 61.06 for all patents, a degree of concentration that is notably higher than even that of overall patenting in the most concentrated sectors. In general terms, this analysis finds that the regional distribution of internationally relevant applications has not changed substantially in recent years. More precisely, the Gini coefficient of regional concentration has decreased only very moderately from 83.98 (2008) to 82.68 (2012). That, however, should not obscure the fact that new clusters of internationally relevant patenting have recently emerged in a number of inland provinces. As Figure 8 illustrates, 5 years ago, only Guangdong exceeded a 10% share of transferred patents in total SIPO applications, a condition that is found in four provinces today. Moreover, the absolute extent of activities has increased substantially in the greater Shanghai area and the Bohai Economic Rim (notably Shandong).

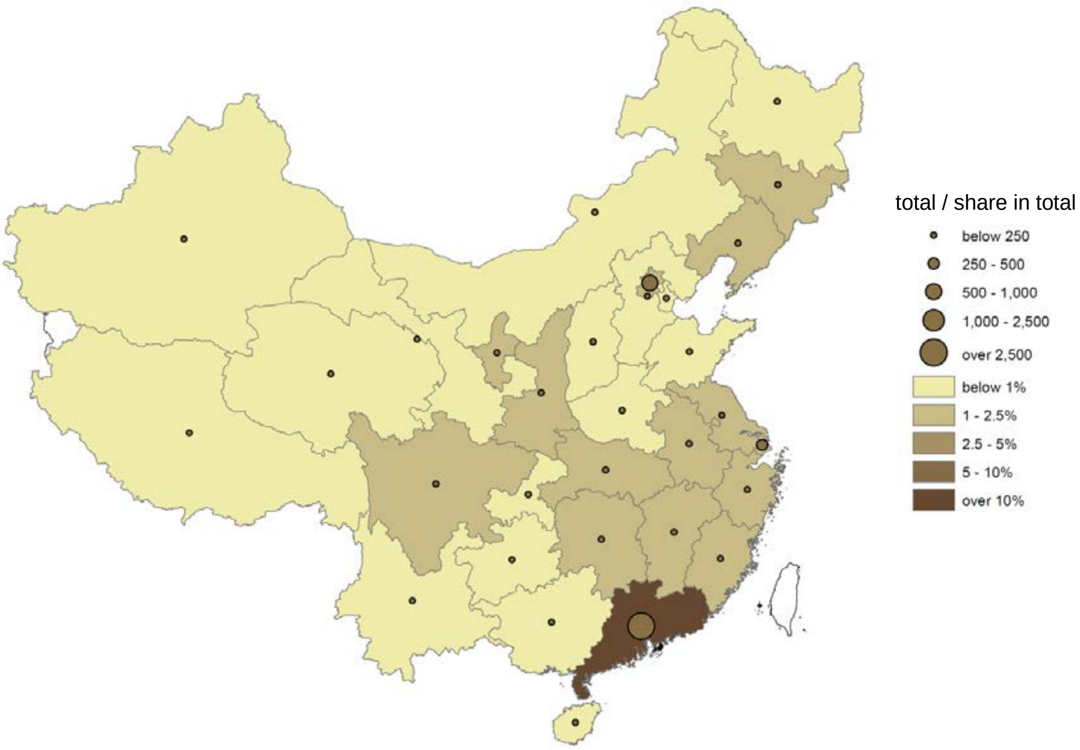
Finally, it appears relevant to highlight that, as foreseen, there are notable differences between the distribution of applications at specific international offices (mostly considered evidence of foreign-invested companies' activities) and transfers to the World Intellectual Property Office (WIPO). These differences are probably related to internationally relevant and/or qualitatively more robust inventions of domestic Chinese firms. As a contrasting example, applications at the Taiwanese office are illustrated in Figure 9.

Figure 7: Share and number of SIPO patents transferred to WIPO via PCT (2012)



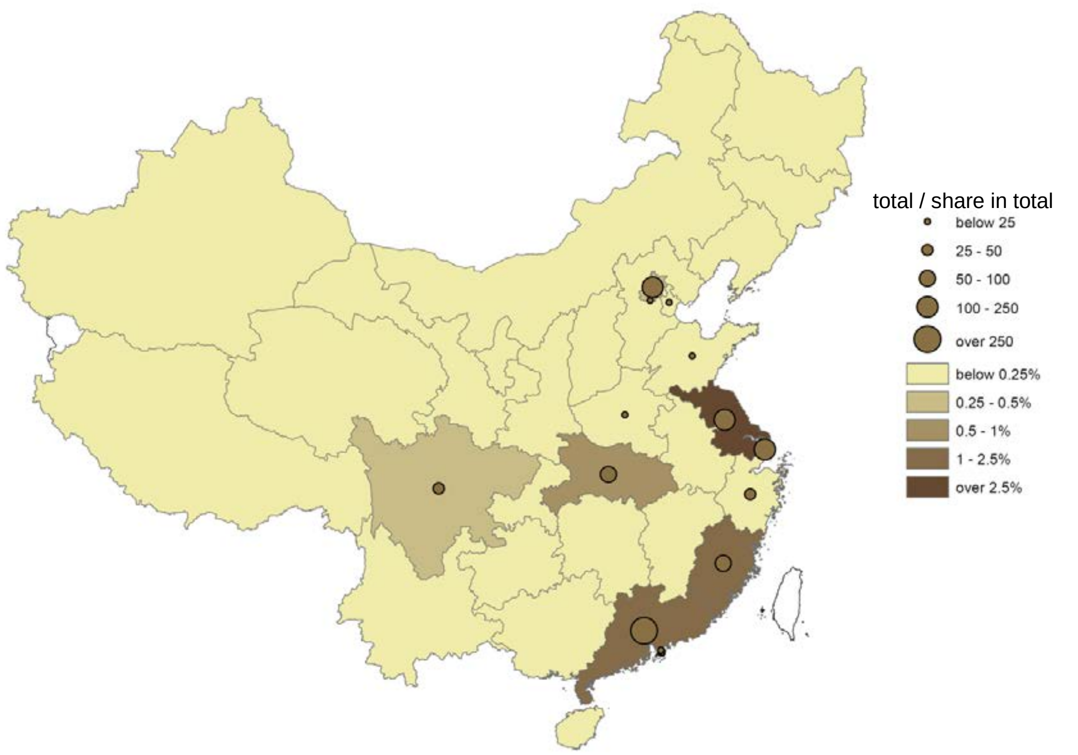
Source: Own analysis, map based on ESRI ArcGIS

Figure 8: Share and number of SIPO patents to WIPO via PCT (2008)



Source: Own analysis, map based on ESRI ArcGIS

Figure 9: Share and number of SIPO patents with family members at the Taiwanese patent office



Source: Own analysis, map based on ESRI ArcGIS

4.2.3 A Classification of Chinese Regions’ Technological Systems

When addressing Hypothesis 3 and considering the diverse patterns and trends documented above, the question arises whether Chinese provinces can be subsumed in meaningful groups for analytical purposes. A cluster analysis was conducted using standard SPSS procedures for centroid-based clustering based on the following variables

- Overall level of activity,
- Share of university patenting in overall patenting,
- Location quotient of 19 key technological fields (ISI19),
- Share of patent applications at four different international patent offices, including PCT transfers through WIPO.

To avoid bias caused by differences in the absolute standard deviation, all variables were subjected to a z-transformation before conducting further analytics.

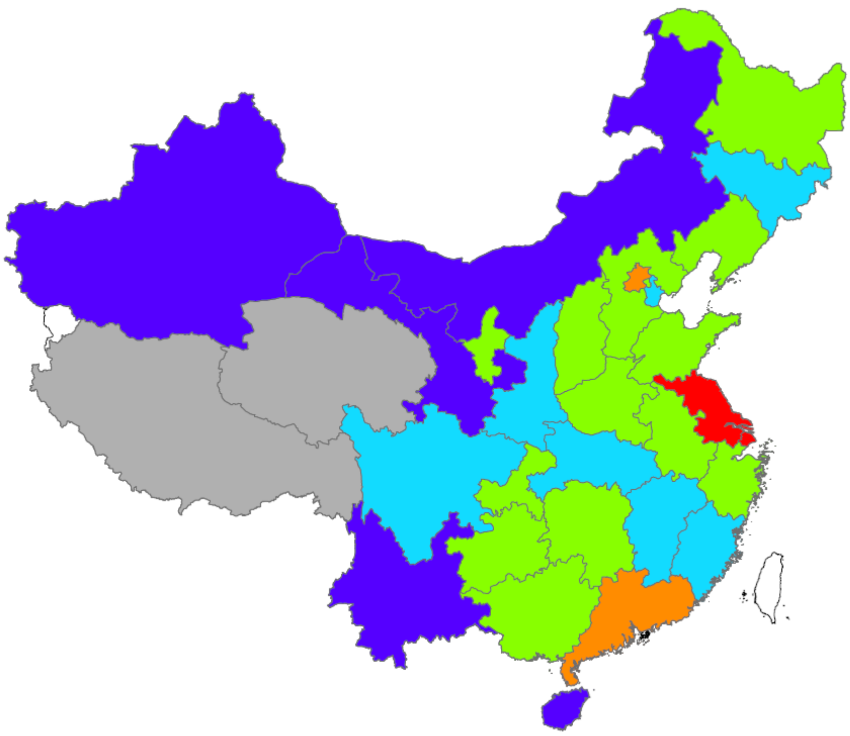
In a first step, the number of desired clusters was set to four, resulting in the outcome presented in Figure 10: two groups of 'leading clusters' Beijing and Guangdong as well as Shanghai and Jiangsu, one cluster of catching-up provinces in Central China and one cluster of truly peripheral regions. While this first step does not yield much additional information, it validates the approach by being in line with common sense and earlier studies.

In a second step, the number of desired clusters was set to six, resulting in the outcome presented in Figure 11: The overall framework remained intact, while both the catching-up and the peripheral clusters were further divided into another two clusters. Before these six clusters are characterised in more detail, it seems worth pointing out that the stability of the overall framework again underlines the robustness of the approach. Moreover, increasing the number of clusters to eight does not produce a new structure, but simply splits the two 'leading clusters' into their constitutive provinces (Figure Annex 20).

Figure 10: Classification of provincial technological systems into four clusters

Source: Own analysis, map based on ESRI ArcGIS

Figure 11: Classification of provincial technological systems into six clusters



Source: Own analysis, map based on ESRI ArcGIS

Table 2 shows the constitutive characteristics of the six clusters. Cluster 1 (Shanghai and Jiangsu), one of the two leading clusters, is characterised by a strong outward orientation, a broad technological basis (with a focus on electronics) and a notable regional share of university patterns. The regional technological profile of Cluster 2 (Beijing and Guangdong) is more focused on IT and telecommunications and this cluster is weaker in traditional fields and its (technological) outward orientation is not as marked as in Cluster 1. Due to the relative scarcity of higher education facilities in Guangdong, the share of Cluster 2's university patenting in overall applications is somewhat lower. However, the patent intensities in both 1 and 2 substantially exceed the national average with 1,475 (Cluster 1) and 1,559 (Cluster 2) patent applications per million inhabitants.

With a view to the catching-up regions, a clear distinction can be made between those that can rely on a strong public research basis in universities (Cluster 4, e.g. Hubei, Shaanxi, Sichuan) and those that largely lack such facilities (Cluster 3, e.g. Anhui, Shandong, Hunan, Guangxi). On the other hand, the international orientation of technological activities is higher in Cluster 3 (even if still quite low) than in Cluster 4. At the same time, those provinces with more pronounced technological activities in the higher education sector show some application activities in 'modern' fields such as IT or telecommunications that are largely absent in the more business- and outward-oriented group focusing on traditional fields. With regard to overall patent intensity, both clusters reach about one sixth to one fifth of the leading cluster's provinces (Cluster 3: 330, Cluster 4: 248). In the following, this differentiation will be used to analyse internal differences within the group of catching-up regions that are quite similar with regard to their mid-range patent intensities, yet differ with regard to the structural composition of their technological systems.

Looking at the two clusters of peripheral regions, the arguably largest point of differentiation is the overall level of patent intensity that is 86.1 in Cluster 5 (e.g. Gansu, Yunnan, Xinjiang), while it remains at a very low 36.2 per million inhabitants in Cluster 6 (Qinghai, Tibet). Neither cluster displays any notable outward orientation. While Cluster 5 still records some university patenting, this is largely absent in Cluster 6. Furthermore, both clusters focus heavily on traditional fields, with a specific focus on chemicals and pharmaceuticals.

Table 2: Characteristics of the six clusters

	Role of public sector	Outward orientation	Technological focus
Cluster 1	Medium share of university patents	Strongest outward orientation	Broad basis, including focus on electronics
Cluster 2	Lower share of university patents	2nd strongest outward orientation	Focus on IT & telecom, weaker in trad. fields
Cluster 3	Medium share of university patents	Limited outward orientation	Broad basis, focus on traditional fields
Cluster 4	Highest share of university patents	Very limited outward orientation	Broad basis, including some modern fields
Cluster 5	Medium share of university patents	No outward orientation	Chemicals, polymers, pharma, textiles
Cluster 6	Hardly any university patents	No outward orientation	Pharma, textiles, some chemicals

Source: Own analysis

4.2.3.1 Technological Systems' Characteristics and Technological Growth

Before addressing Hypothesis 4, this subchapter of the results section explores the relation between specific characteristics of Chinese provinces' technological systems and the overall growth in SIPO patent applications observed in the periods 2008-10 and 2010-12.

A two-step strategy is followed:

Firstly, a backward stepwise regression is conducted with overall patent growth as the dependent variable. The relation of international family members to the total number of SIPO applications as well as the share of university patents in all SIPO applications are used as the main explanatory variables, while controlling for sectoral or field-specific structures by including the location quotients of all ISI19 fields at the same time.

Secondly, growth rates from 2008-10 and 2010-12 are determined and analysed separately by cluster. With a view to the continued dominance of some major provinces (generally the four classed as 'leading clusters'), the results of overall models are likely to be dominated by developments here. Against this background, a cluster-based analysis appears suitable to explore additional differences *among* catching-up regions.

As illustrated in Table 3, the first finding is that there has been a structural change between the growth process observed from 2008-10 and that prevalent from 2010-12. Between 2008 and 2010, outward orientation was strongly and positively correlated with growth. This probably reflects a situation in which regions with a high level of foreign investment or prominent national firm headquarters were reinforcing their leading position. Remarkably, however, the original level of technological activity had a slightly negative impact on growth, indicating that, even at this time, some catch-up processes were underway. In following period from 2010 and 2012, growth in patenting was no longer associated with the international relevance of local patenting, nor did it in any way depend on the initial level of activity. Instead, the role of the university sector in the local technological system had become an important factor, significantly and positively correlated with overall growth in SIPO applications. Additionally, there are different technological control variables significant in each period with only one overlap, the negative correlation of specialisation in general machinery with growth. Beyond that, the findings for the first period mirror the positive influence of international orientation. Growth in computer technology and audio-visual electronics is positively linked to a strong outward orientation, while specialisations in more domestically-oriented fields like chemicals or general machinery have a negative influence. One exception to this rule is the negative influence of telecommunication technologies between 2008 and 2010, possibly reflecting a relative decrease in growth in the already dominant regions of Beijing and Guangdong. During the 2010-12 period, in contrast, there is no such intuitive pattern. Machine tools is the only type of specialisation during this period that is positively associated with growth, whereas the somewhat incoherent group of pharmaceuticals, measurement and control technologies, optics, non-polymer materials and medical equipments display a negative correlation.

In anticipation of the later discussion, there are two possible interpretations of these tendencies. Firstly, it is possible that the national government's push of 'indigenous innovation' is indeed bearing fruit in that more technological output is now being generated in industrial sectors less dominated by foreign investors and technologies, and that the Chinese market has become more important as a technological point of reference. Secondly, however, the analysis may simply be reflecting an increase of low-quality (internationally not relevant) patenting in response to political target setting. This is associated with public players like universities as these are more likely to translate such targets directly than foreign-invested firms or domestic Chinese technology firms with a world market orientation.

Table 3: Stepwise model identifying correlations between application structure and growth

	Growth in patent applications 2008-2010		Growth in patent applications 2010-2012	
Key explanatory variables				
Family members abroad	1.051	**		
Relation to SIPO Total	*0.293*			
University patents			1.676	°
Share in SIPO Total			*0.824*	
Controls				
No. applications initial year	-0.000	**		
	0.000			
LQ special machinery	0.341	***		
	0.078			
LQ audio-visual tech.	0.189	*		
	0.088			
LQ computer tech.	0.268	*		
	0.104			
LQ general machinery	-0.450	***	-0.436	*
	0.087		*0.171*	
LQ basic chemicals	-0.476	***		
	0.080			
LQ telecommun. tech.	-0.362	**		
	0.128			
LQ machine tools			0.257	**
			0.077	
LQ pharmaceuticals			-0.128	*
			0.052	
LQ measure control tech.			-0.415	*
			0.173	
LQ non-polymer materials			-0.174	°
			0.085	
LQ optics			-0.183	*
			0.086	
LQ medical equipment			-0.202	°
			0.117	
R-sq-adj	**0.586**		**0.476**	
N	**31**		**31**	

Note: °: p <= 0.10; *: p <= 0.05; **: p <= 0.01; ***: p <= 0.001.
LQ = Location Quotient: Share in Regional Total vs. Share in National Total
Source: Own Analysis

As illustrated in Table 4 and Figure 12, the analysis yields even more differentiated insights. During the period 2008-2010, differences in growth were not significant in terms of an overall F-statistic. In terms of cluster-specific averages, however, a certain downward trend could be identified for the leading provinces in Cluster 2 (Beijing, Guangdong), while the catching-up regions in Cluster 4 (those with a strong university basis) display an upward trend. The overall variation within the groups, however, was too high to make these differences significant. During the period 2010-2012, in contrast, technological growth differences between clusters become significant in terms of F-statistics. There is a strong upward trend of the catching-up regions of Cluster 3 (those without strong university basis and focused on traditional industries) and a notable downward trend of the genuine periphery (Cluster 6). At the same time, the formerly notable growth differences between leading regions are somewhat mitigated.

Table 4: Growth of SIPO patent applications differentiated by period and cluster

2008-2010

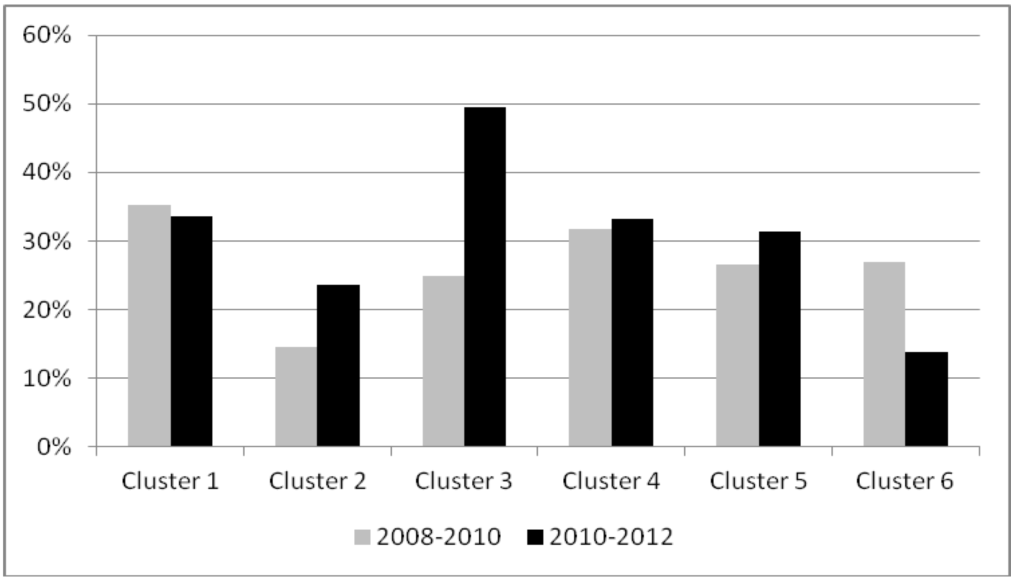
	Cluster 1	*Cluster 2*	*Cluster 3*	*Cluster 4*	*Cluster 5*	*Cluster 6*	**F**	**p Value**
Mean	0.352	0.146	0.248	0.318	0.265	0.269	0.665	0.653
Std. dev.	*0.198*	*0.085*	*0.152*	*0.137*	*0.085*	*0.180*		

2010-2012

	Cluster 1	*Cluster 2*	*Cluster 3*	*Cluster 4*	*Cluster 5*	*Cluster 6*	**F**	**p Value**
Mean	0.335	0.236	0.495	0.332	0.313	0.137	2.286	0.077
Std. dev.	*0.204*	*0.028*	*0.229*	*0.097*	*0.131*	*0.149*		

Source: Own analysis

Figure 12: Growth of SIPO patent applications differentiated by period and cluster (diagram)



Note: Cl. 1 & 2: Leading regions, Cl. 3 & 4: Catching-up regions, Cl. 5 & 6: Peripheral regions
Source: Own analysis

Interestingly, the relationship between regional structure and growth patterns among catching-up regions clearly differs from the general trend as identified in the regression model. Contrary to the overall picture, a high share of university patenting was not conducive to increased growth among catching-up provinces. Instead, regions like Zhejiang, Anhui, Shandong, and Guangxi joined the catching-up process to a greater extent. This does not imply that growth rates in the public-oriented 'Cluster 3' regions decreased. Instead, the annual growth rate of large second order provinces with a public basis like Sichuan, Shaanxi, or Chongqing remained the same or increased moderately. Consequently, their absolute contribution to technological growth and convergence still eclipses that of smaller, more business-oriented 'Cluster 4' regions.

These findings constitute evidence that a new process or trend emerged around 2010 that has triggered a new wave of SIPO patent applications in provinces that used to be technologically less developed and that still today mostly rely on mature industries that are less oriented to world markets. At the same time, there is no reason to assume that all the industrial sectors of these provinces are by definition more state-oriented than others and thus more receptive and responsive to political target setting (quite the contrary, for example, seems likely in Zhejiang and Shandong). Hence, political pressure alone does not explain these findings.

5 Discussion

With a view to the four main hypotheses, the following findings can be reported:

Firstly, recent developments in China's technological system do not indicate that any substantial mitigation of geographical disparities is imminent. While there is notable evidence of a strengthening of many non-coastal regions, the continued dynamics of the Greater Shanghai region in particular precludes an overall decrease in measures of disparity.

Secondly, the pattern of technological specialisation among Chinese provinces has remained mostly stable throughout the past five to ten years. Nonetheless, the former extreme regional concentration of world market-oriented capacities in some fields seems to be waning as the result of a spread of technological capabilities. At the same time, the degree of concentration of university patents has substantially decreased as actions and policies supporting technological transfer that were formerly limited to 'islands of innovation' have become more and more prevalent in China's interior. Finally, while the regional concentration of patenting activities with international relevance may not have decreased in general terms (as this continues to rise in the leading regions), it has nonetheless increased substantially in a number of inland provinces in both absolute and relative terms.

Thirdly, China's provinces can indeed be classified into six main groups based on the extent and composition of their regional patenting activities. Doing so reveals both different and distinct starting points for future pathways of regional development, not only among the leading, but also among different types of catching-up regions. The well-known differentiation between Beijing, Greater Shanghai and Guangdong's Pearl River Delta should thus be complemented by a further classification of the technological “mid range” provinces.

Fourthly, there is indeed a notable influence of the aforementioned regional characteristics on the recent growth in patent applications in Chinese provinces. More importantly, there is evidence of a structural change that, in terms of timing, corresponds to the latest surge in Chinese patenting – and that many outside observers believe to be politically induced. In the overall system, apparently, the public sector plays a role positively associated with further growth. At the same time, the opposite holds true for recent developments in catching-up regions, where those *without* a strong public research basis seem to be experiencing stronger relative growth than before.

As outlined in the introduction, this paper lacks the methodological basis to explain any of these developments in the sense of identifying robust causalities. Nonetheless, it is still remarkable to see undeniable changes occurring in the wake of a new major political initiative supporting 'indigenous innovation'. While it is unclear whether the newly emerging correlation between patent growth and a strong role of the public sector implies that the patents responsible for growth actually originate from universities, it appears noteworthy that growth is occurring in locations considered more responsive to political target setting. This impression is reinforced by the fact that patenting grew substantially in central government-oriented Beijing (8% vs. 25%), while it remained comparatively stable in the regions of Guangdong (21% vs. 22%) and Shanghai (21% vs. 19%) which are said to react more sluggishly to central government policies.

At the same time, there seems to be a different logic of technological growth in catching-up provinces. In these provinces, the lead is now being taken by a group of formerly less dynamic, business-oriented regions characterised by mature industrial sectors. There are two speculative explanations for this. On the one hand, it could be argued that this development is 'not real' but merely a reflection of the new policies demanding a contribution of these provinces to the nation's push towards 'indigenous innovation', irrespective of their 'true' technological capacity. The fact that many of these regions still generate very low shares of patents with international relevance could be considered evidence of this. On the other hand, it can be argued that the findings reflect, if not increasing technological activity, an increasing acknowledgement that even incrementally improved, mature products for the domestic market can and should be protected by patenting. Beyond the general observation that more and more experts are suggesting that the Chinese IPR system has become substantially more robust in recent years, this argument is also backed by the study’s finding that several more traditional sectors are concentrating geographically, which is typically also a form of secondary evidence for a 'real' change in the role that technology and inventions play for the production process.

In summary, this study has revealed some evidence of political interference with the evolution of the national technological system as well as genuine changes in many regions' technological capacities. To what extent the latter is the result of the former or is due to other technological and global economic developments remains beyond its capacity to explore.

6 Conclusions

Our study finds evidence of substantial changes within the national system of knowledge production in China. New players are entering the stage while established ones seek to reinforce and improve their positions. While, in general terms, this statement holds true at the level of firms and institutions, this study has focused on showing that it is also clearly reflected at the aggregated level of provinces as well. While regional disparities remain stable at an overall level, significant shifts can be observed.

As the analyses presented in this paper strongly suggest, existing structures define the reference framework for future growth and constitute leverage points for technological trends and policies targeting new activities. While the effectiveness of each emerging trend and each new policy is influenced by existing structures, they will at the same time have a lasting impact on them (as well as the provinces' relative position to each other). Hence, they can and will change the very foundations upon which their effectiveness was originally based.

Against this background, it is difficult to sum up the quality of this paper's findings in one or two sentences. In line with earlier studies, this study found there is ample reason to doubt whether the current growth in Chinese patent applications is a genuine reflection of increasing technological capabilities. Based on what we know about the technological capacities of the catching-up provinces studied, many of their apparent inventions may be politically engineered or at least encouraged.

Still, past experience has shown that major changes in China begin gradually and the attempt to separate political engineering from 'genuine' technological and economic development may well be a futile exercise in what is one of the world's most strongly coordinated economies. As witnessed for domestic universities’ technology transfer activities and the establishment of foreign enterprises’ R&D laboratories, politically-induced 'labels' have often prepared the ground for subsequent dynamic fields of activity and 'empty shells' have been turned into thriving hubs.

Hence, it may well be that while inventors in catching-up regions are currently often filing bogus patents 'on request' in an effort to meet political targets, doing so will nonetheless acquaint them with the process as such. In a few years time, with strengthened capabilities, they may well be in a position to forcefully exploit that knowledge. Overall, the author thus considers this study to be one more piece in the large mosaic documenting China's growing technological capabilities. In that sense, the observed changes in regional patterns of patent application can be considered 'real' and worthy of external observers' attention.

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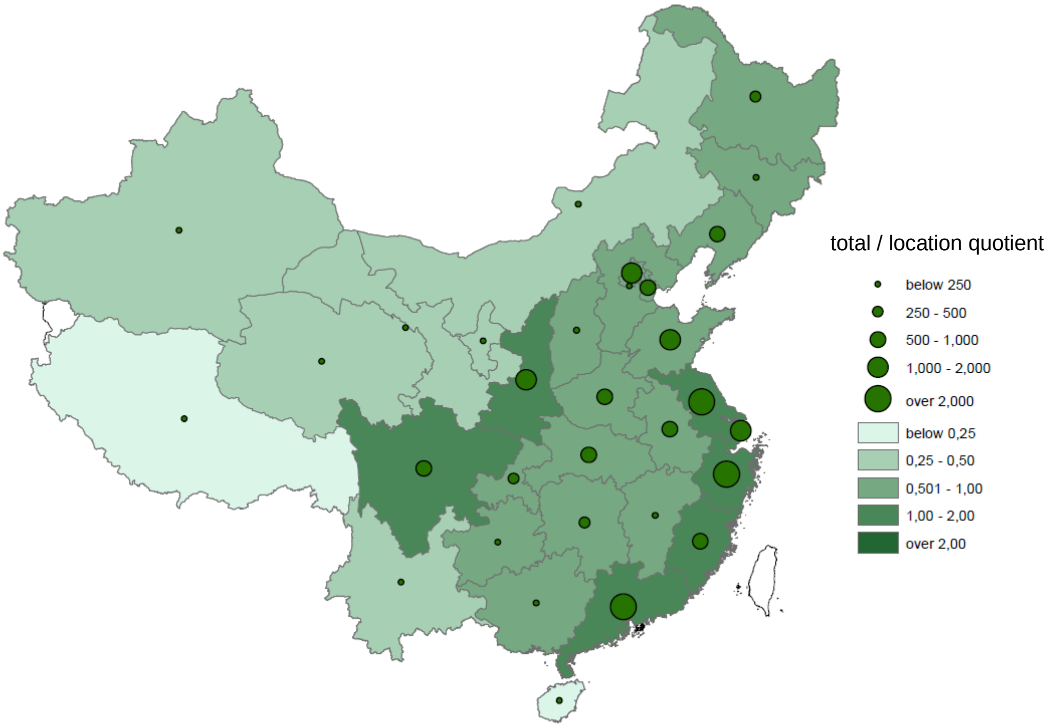
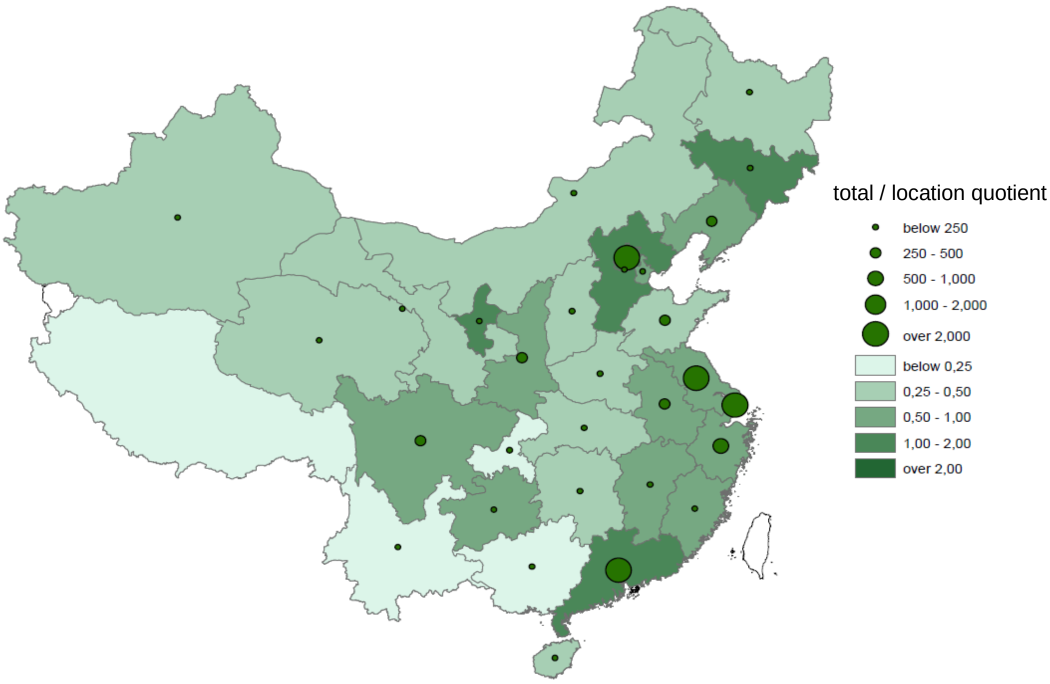
Figure Annex 1: Regional distribution of applications in the field of electrical machinery



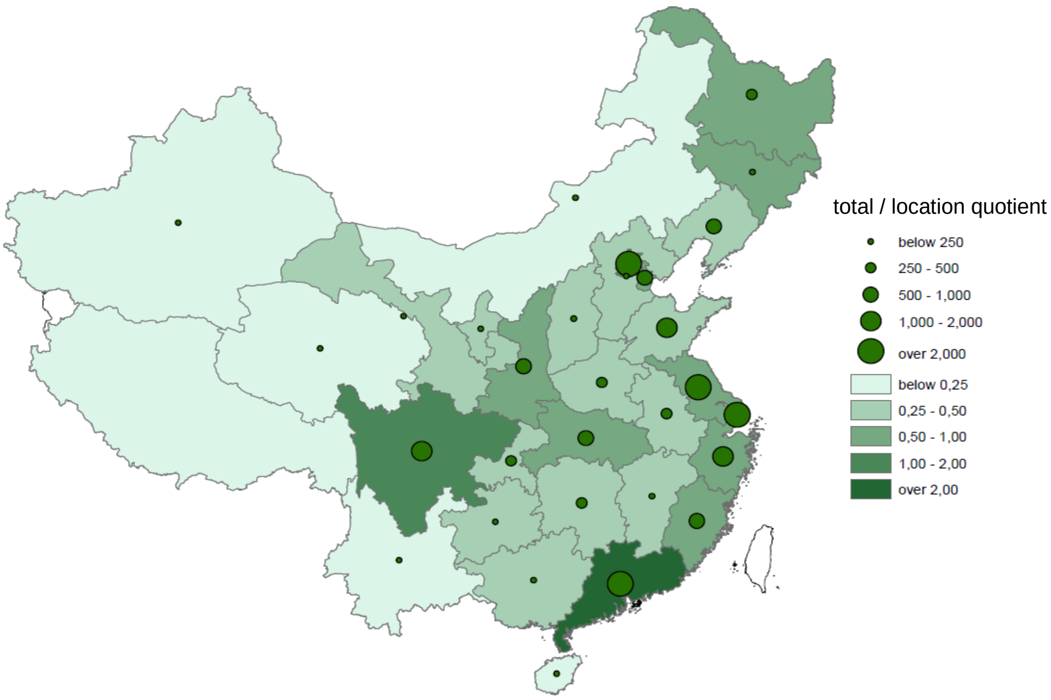
Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 2: Regional distribution of applications in the field of electronic components



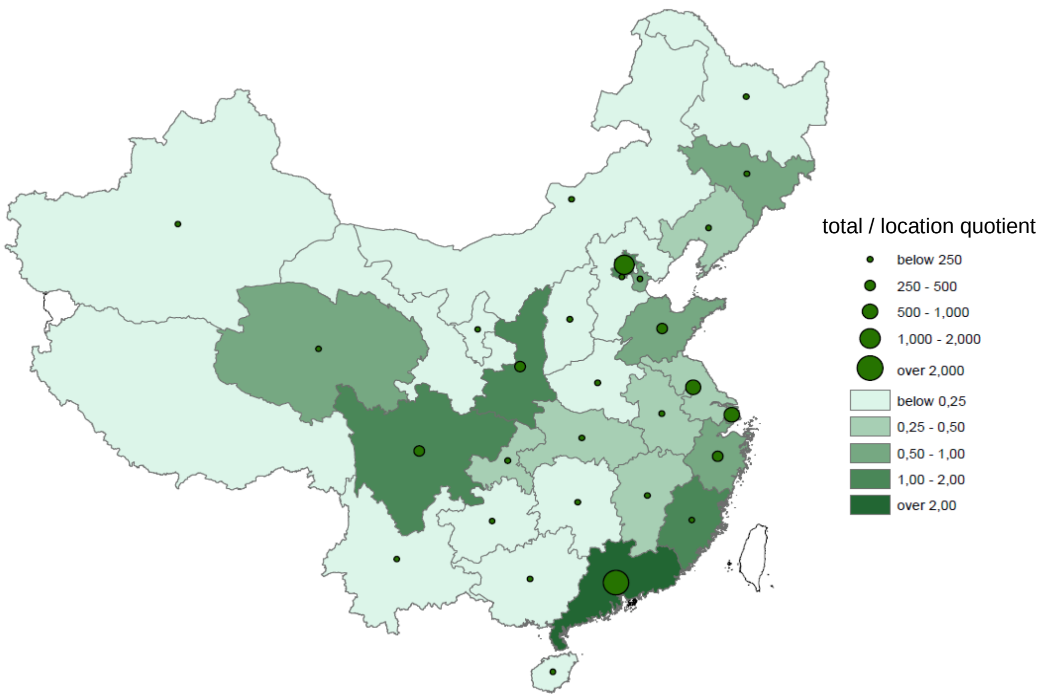
Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 3: Regional distribution of applications in the field of telecommunications



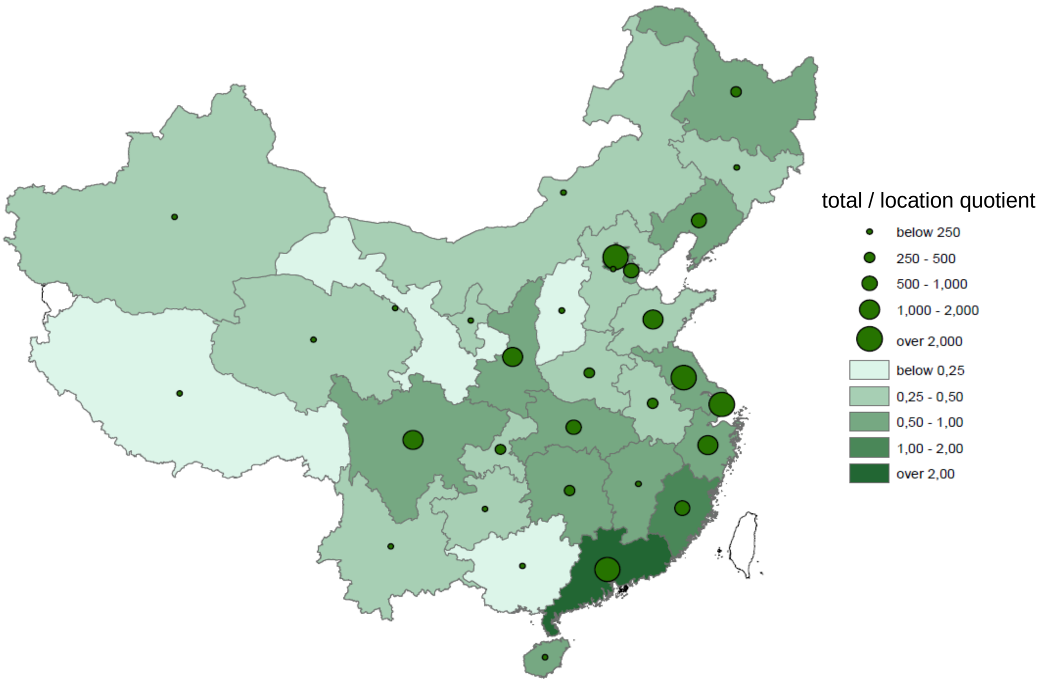
Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 4: Regional distribution of applications in the field of audio-visual electronics



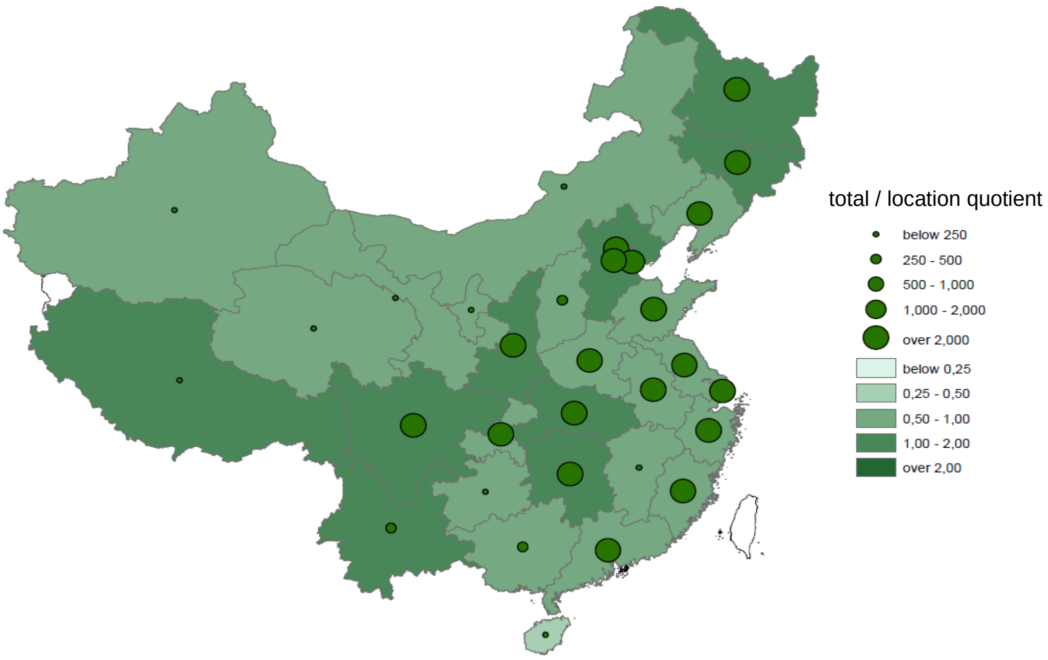
Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 5: Regional distribution of applications in the field of computers



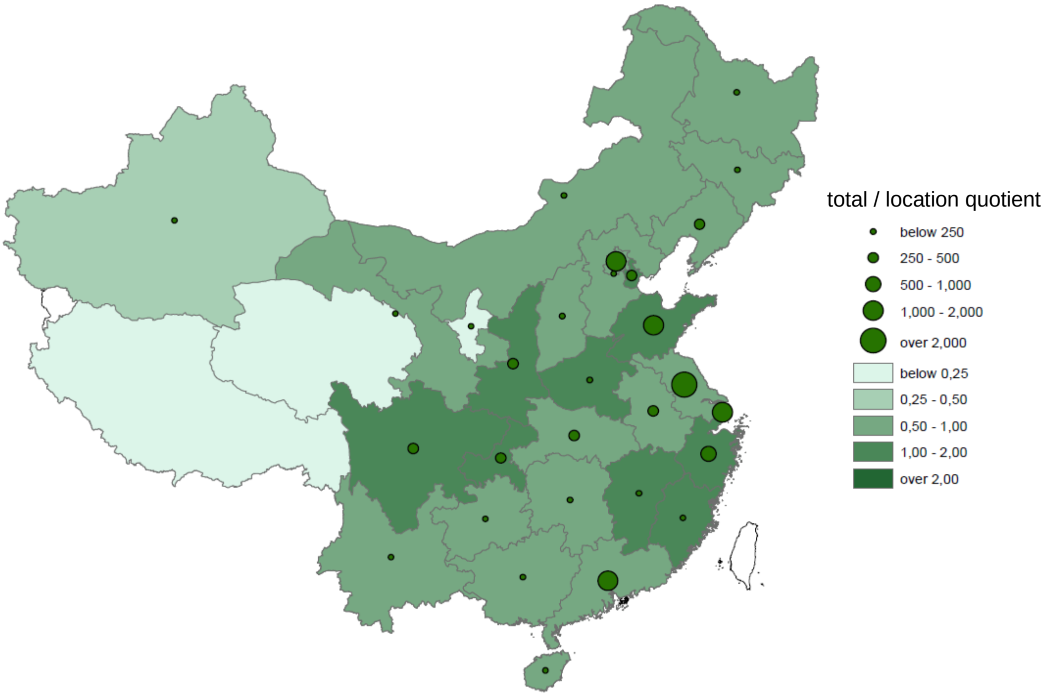
Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 6: Regional distribution of applications in the field of measurement and control



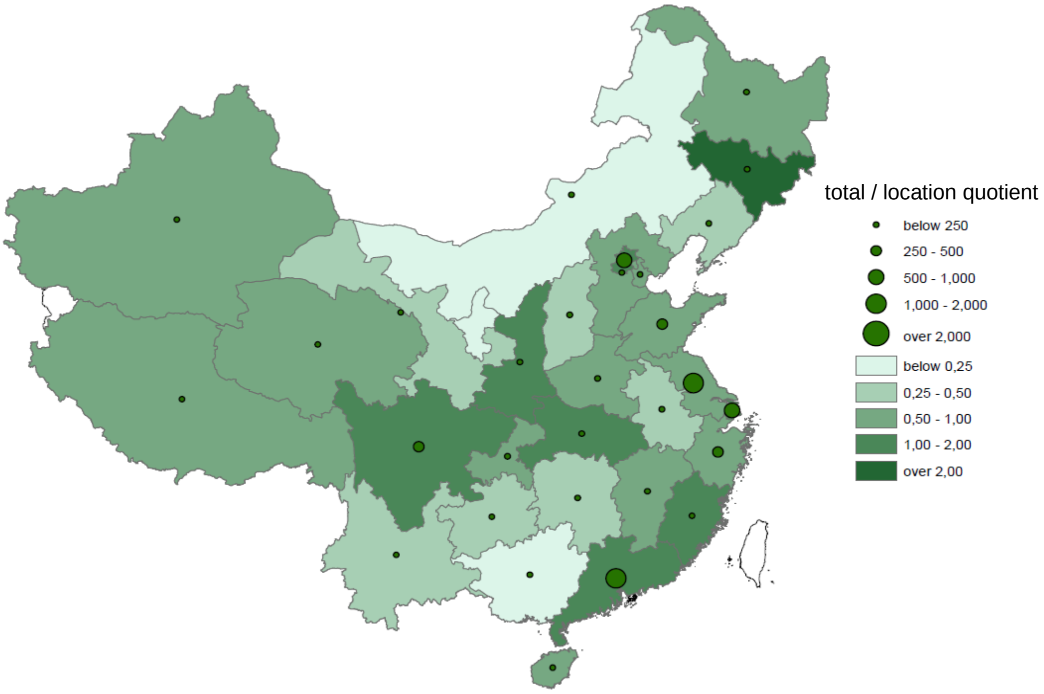
Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 7: Regional distribution of applications in the field of medical equipment



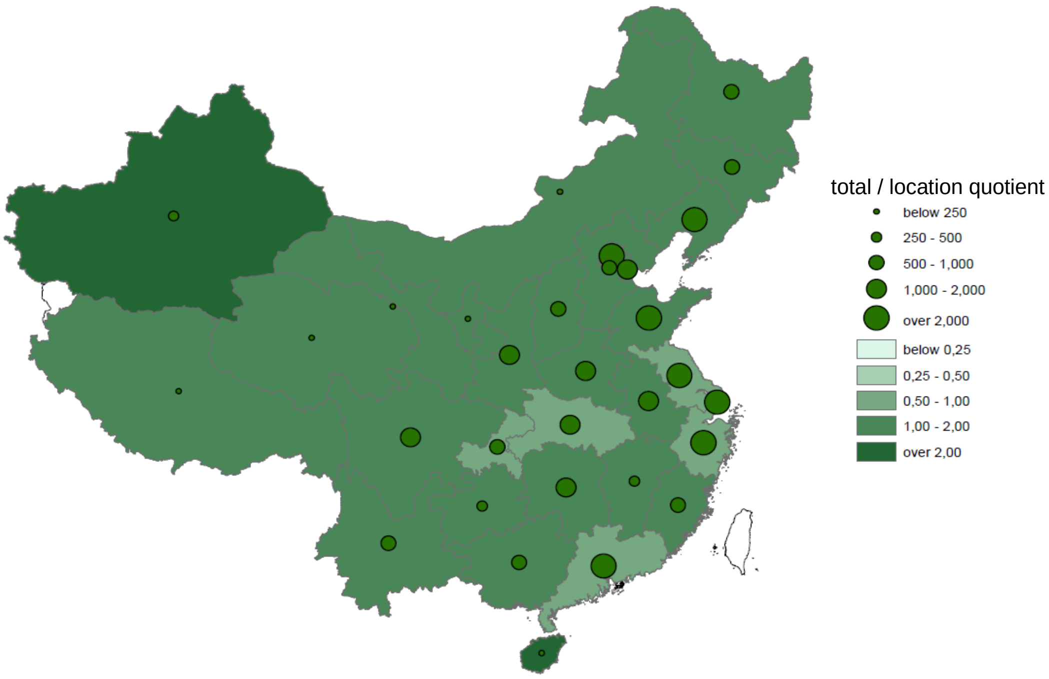
Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 8: Regional distribution of applications in the field of optics



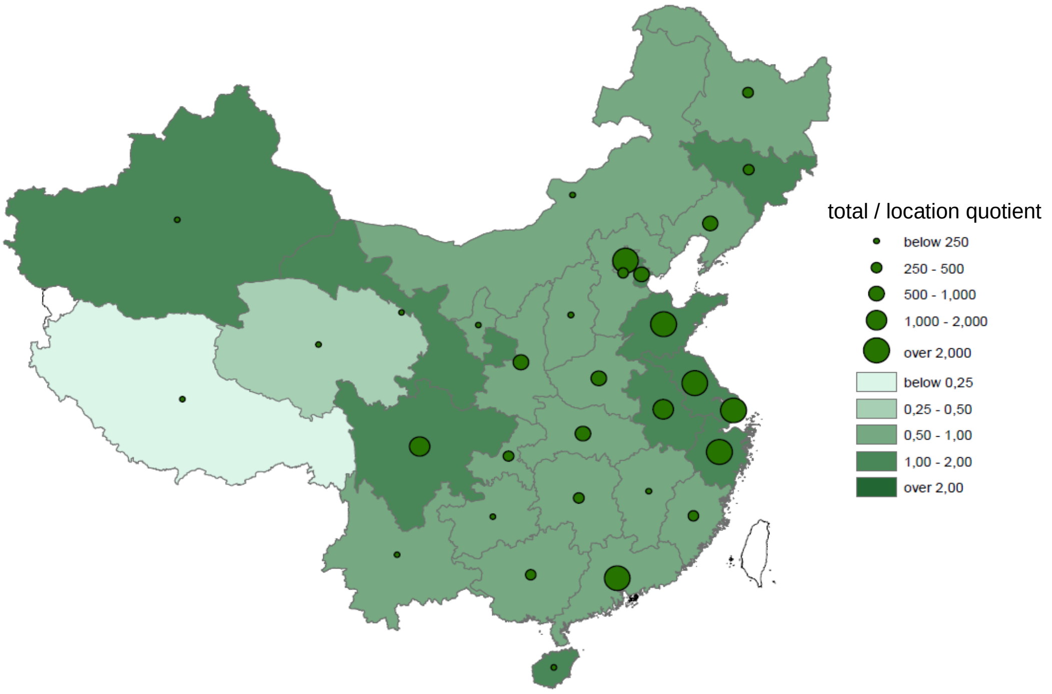
Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 9: Regional distribution of applications in the field of basic chemicals / petroleum



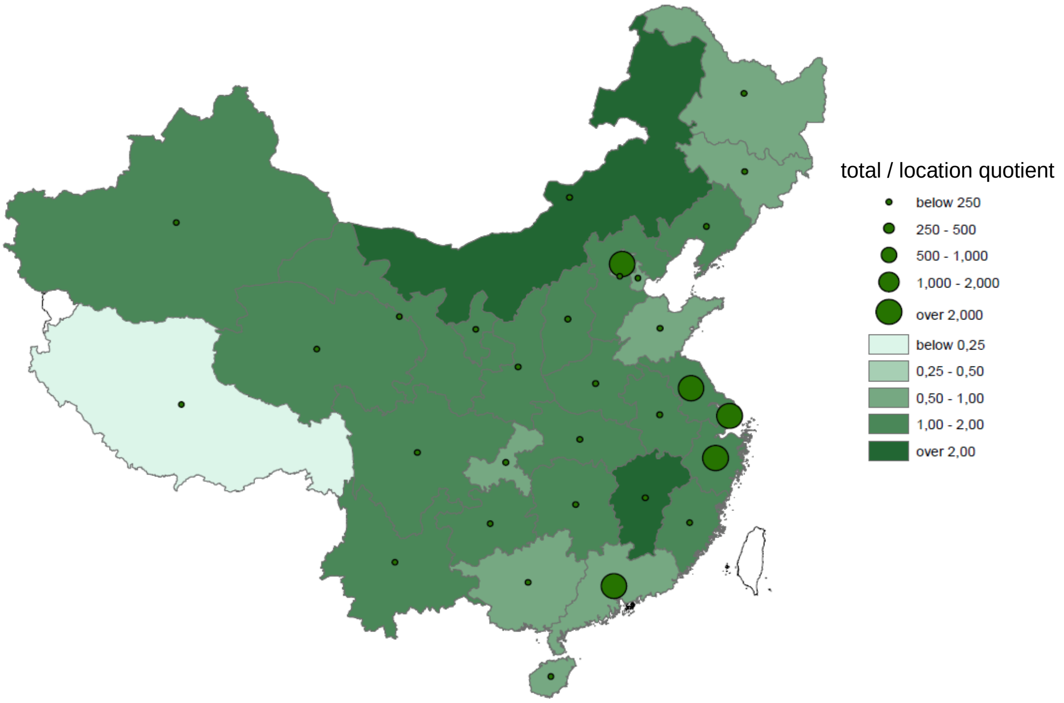
Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 10: Regional distribution of applications in the field of polymers, rubber and fibres



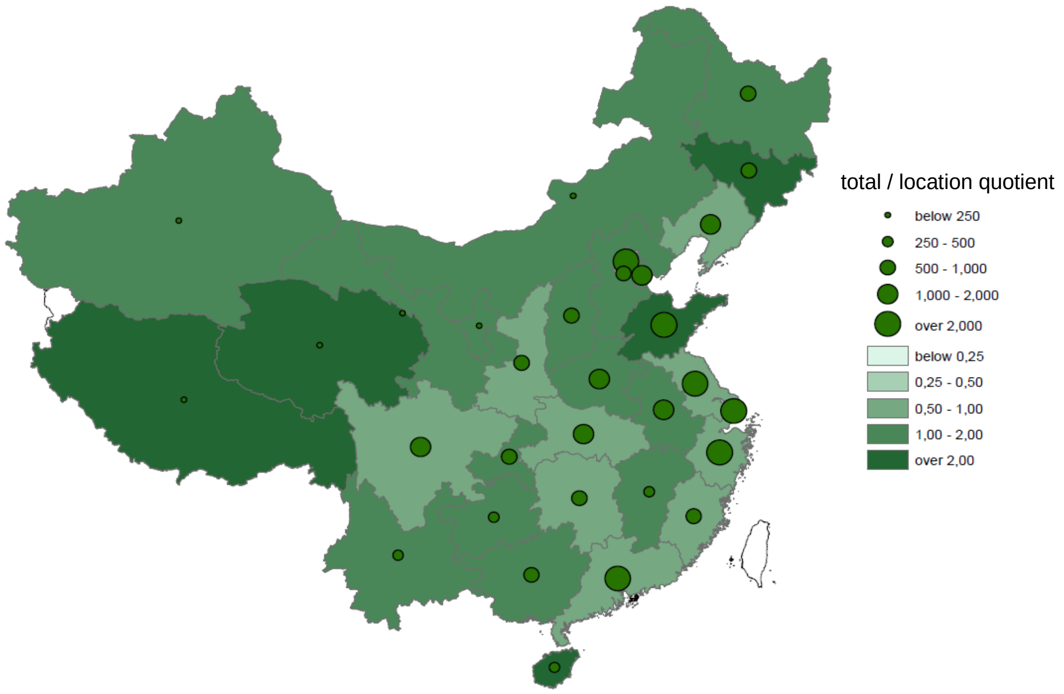
Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 11: Regional distribution of applications in the field of non-polymer materials



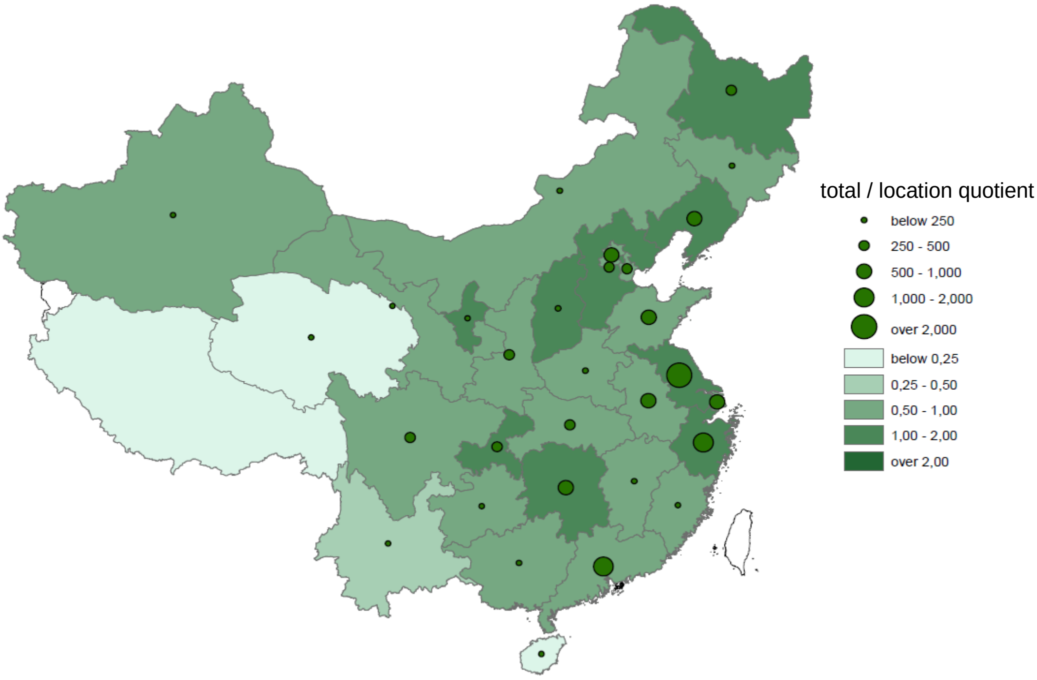
Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 12: Regional distribution of applications in the field of pharmaceuticals



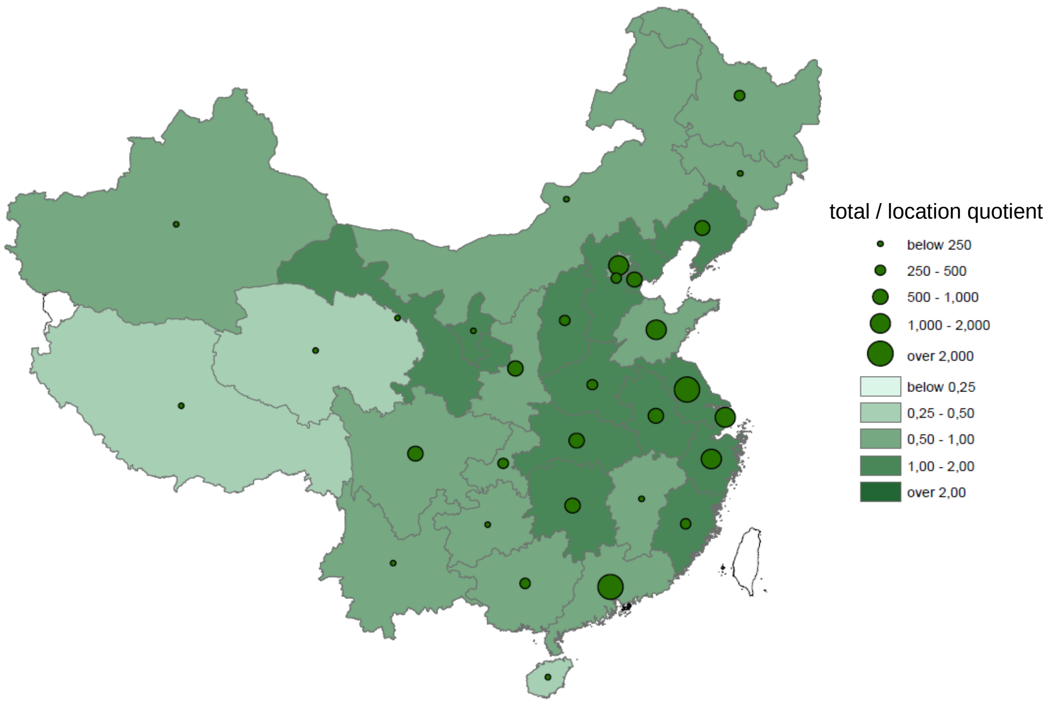
Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 13: Regional distribution of applications in the field of energy machinery



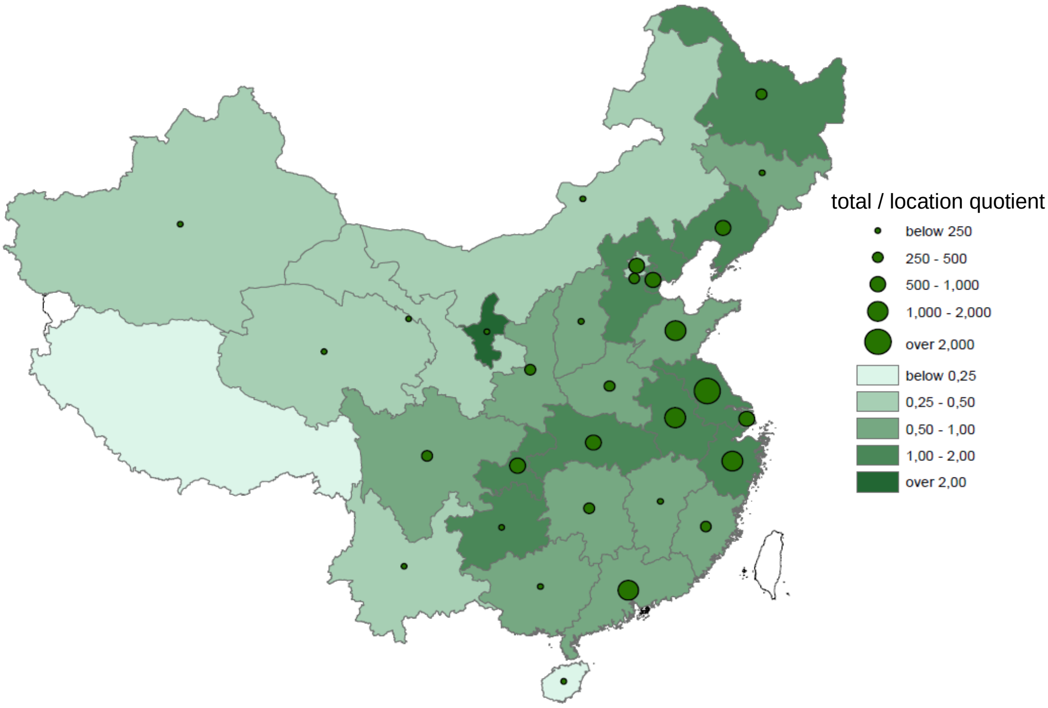
Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 14: Regional distribution of applications in the field of general machinery



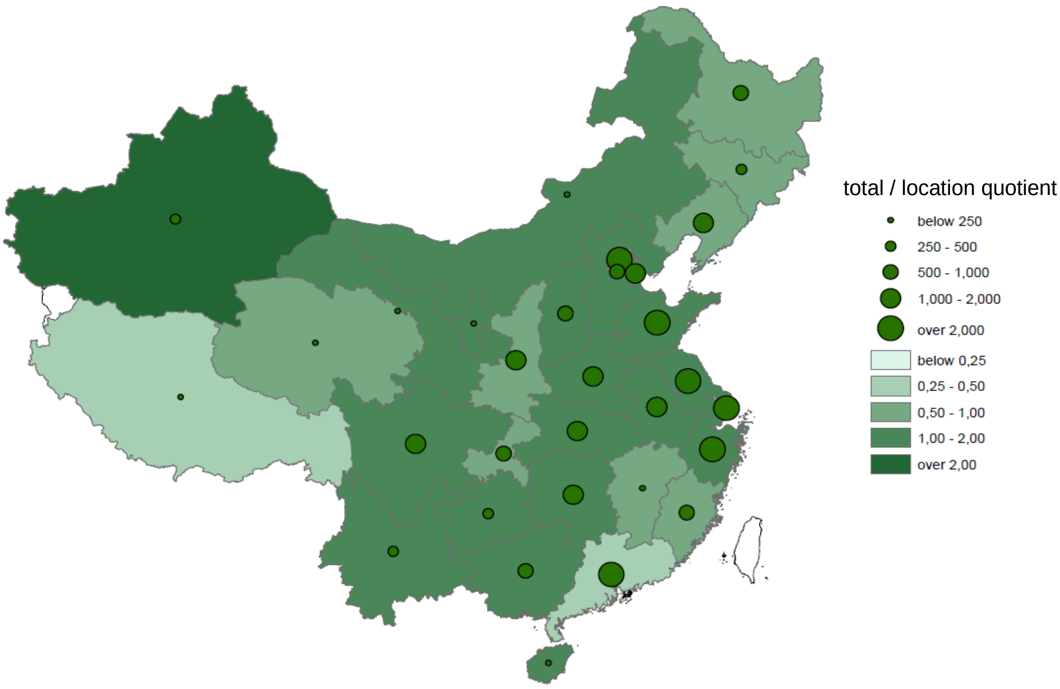
Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 15: Regional distribution of applications in the field of machine tools



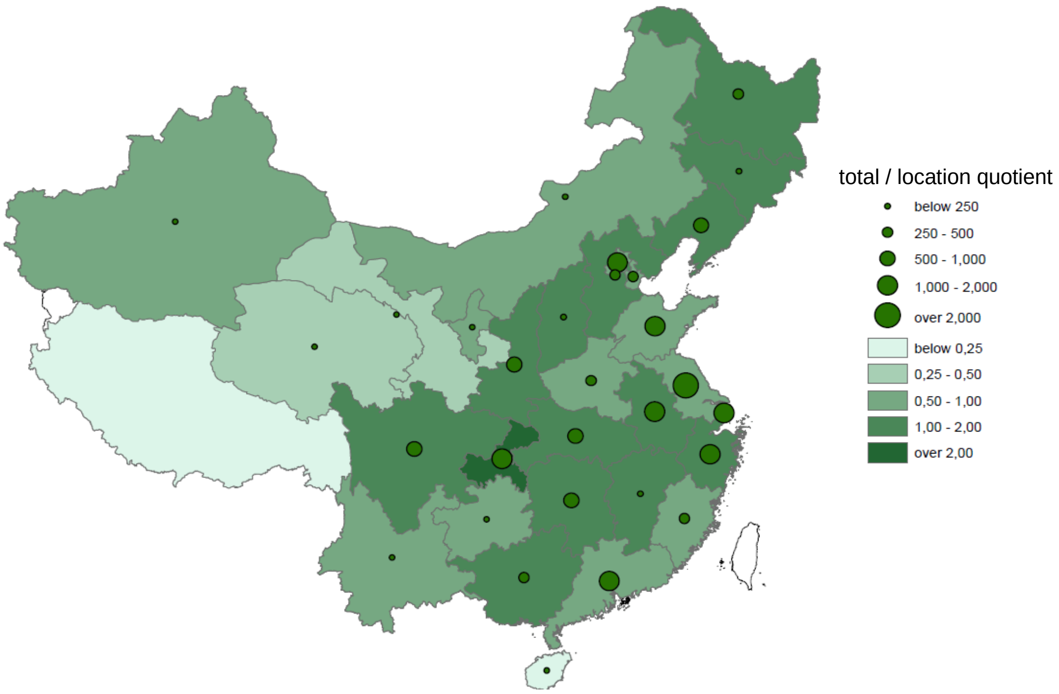
Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 16: Regional distribution of applications in the field of special machinery



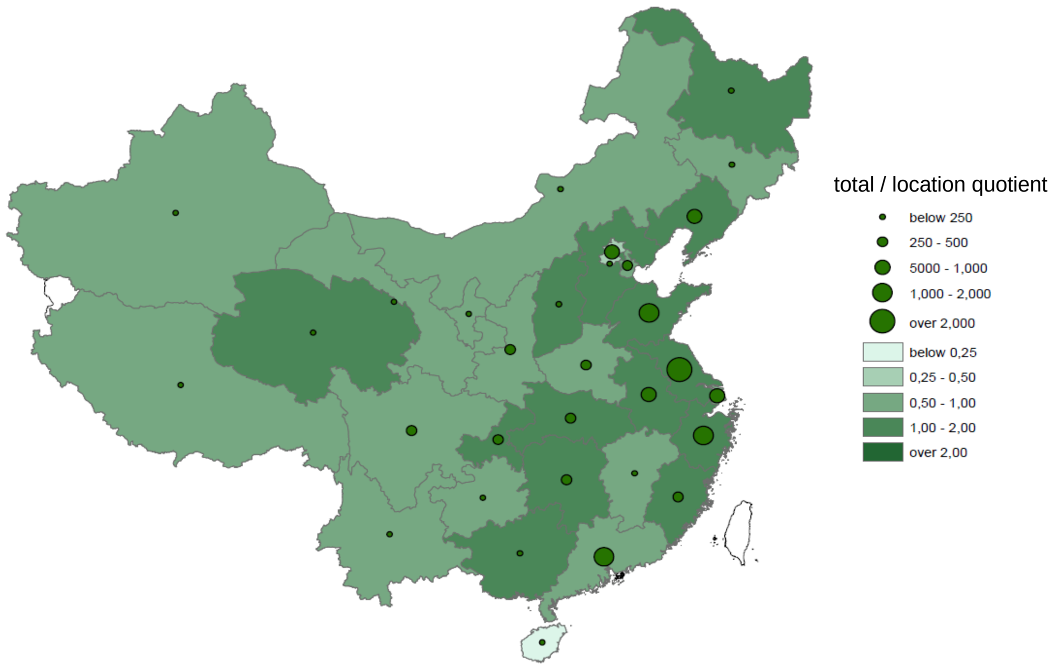
Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 17: Regional distribution of applications in the field of transport



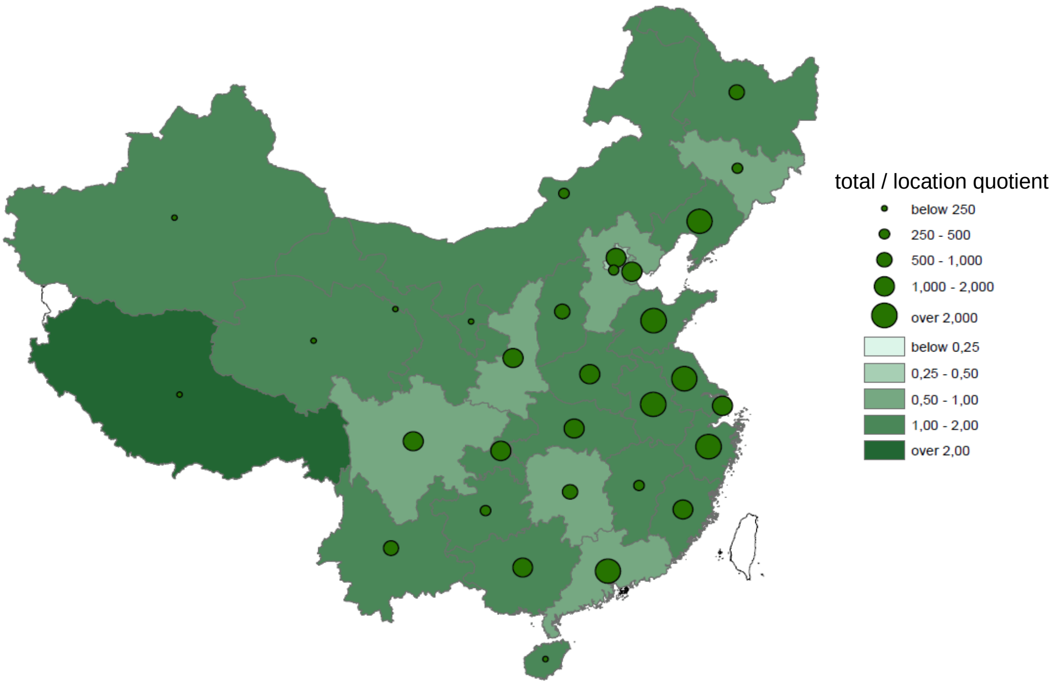
Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 18: Regional distribution of applications in the field of metal products



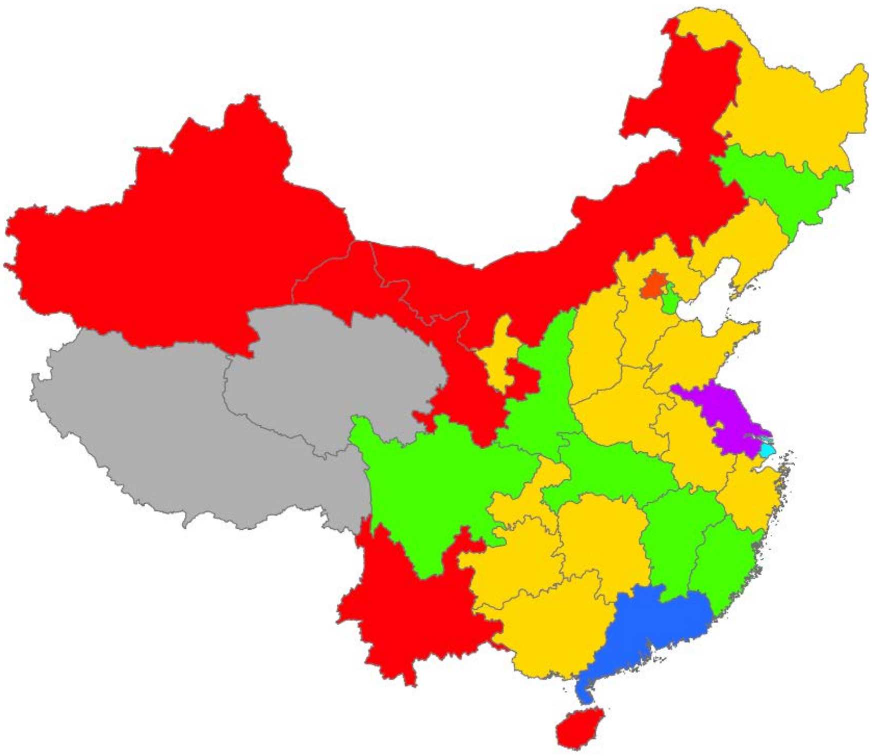
Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 19: Regional distribution of applications in textiles, paper, dom. appliances, food etc.



Note: Map indicates concentration (totals in regions) and regional specialisation (location quotient)
Source: Own analysis, map based on ESRI ArcGIS

Figure Annex 20: Classification of provincial technological systems into eight clusters



Source: Own analysis, map based on ESRI ArcGIS

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