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Exploring pathways of regional technological development in China through patent analysis

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ABSTRACT

Recently, China has experienced a surge in patenting and become the leading applicant nation worldwide. The technological substance of this growth, however, has become increasingly doubted as China's governments continue to promote patenting as a target per se. Against this background, the paper explores the structure of Chinese patenting from a regional perspective. Firstly, it analyses the technological profile, public component and outward orientation of specific provinces' technological ecosystems. Secondly, it connects these specific profiles to regions' recent growth in patent applications. Concluding, it finds that there are indications of both politically induced and technologically substantial growth in applications.

1. Introduction

In the course of the past two decades, China has evolved from a mainly manufacturing nation to a technologically dynamic one with the ambition to catch up with the world's leading economies by 2050 [1,2]. Since 2011, it has become the nation with largest annual patent output in the world [3,4]. At the same time, however, it remains a large country, in which substantive disparities continue to prevail, in general economic as much as in technological terms [5–8]. For a long time, talking about new technological trends and growing capacity in China was synonymous to talking about new developments in Beijing, Guangdong, and Greater Shanghai [9,10]. At the same time, it also 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 [11], but also in terms of their geographical representation [9,10]. As a result, meaningful knowledge transfer between the two only occurred in a limited number of 'islands of innovation', where regionally unique systems of co-operation had developed over the years [10,12,13].

Five years ago, this author gave a comprehensive overview of the regional distribution of research and innovation activities in China, which complemented earlier studies [7] and relied on data up to 2008 available at that time [5]. This study provided a snapshot of a Chinese economy in which both basic research and technological development had begun to play a substantial role, while a strong regional, sectoral and technological concentration of R&D activities continued to prevail. This was particularly marked for those technological activities measurable in patents.

More recent anecdotal evidence suggests that this picture has since changed [13]. Moreover, recent cross-sectional analyses of patent data suggest that technologically advanced industries are moving further inland, while additional regional innovation systems have developed outside the traditional 'islands of innovation' [14]. In parallel, an increasing number of central and local government policies are emphasising 'self-sufficient' or 'indigenous' innovation as well as the need to improve meaningful science-industry collaboration across the country [15]. At the very least, this push has induced substantial efforts to bridge the gap between the public and the private sector [2,16,17]. Despite these new trends, however, the existing technological hotspots of Beijing, Greater Shanghai and Guangdong continue to develop dynamically and consolidate their leading position [9,18].

2. Conceptual background

As prior studies have shown, many transforming innovation systems tend to be characterised by strong dependence on external,

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international knowledge inflows. In China's provinces, the broad basis of foreign-invested technology firms that has developed over the past few decades has created a framework for efficient external knowledge adaptation and processing that differs markedly from that of most Western countries [19–22]. For quite some time, however, these foreign firms' activities did in many places not connect strongly with other parts of the Chinese economy [23]. At the same time, China also harbours substantial capacities in its diverse domestic public research sector [9,10]. While, with a view to its dependence on external knowledge inflows, it may display some structures similar to that of a developing nation, it differs markedly with a view to its substantial, endogenous capacity for knowledge generation, in particular at universities [12,24], which remains unmatched among all the emerging economies [1,2]. For quite some time, therefore, China has overcome its formerly very pronounced dependence on foreign knowledge inflows and its government is eager to support and promote any opportunity for "indigenous innovation", i.e. new developments based on national sources of technology [1,4,25–27].

Secondly, transforming innovation systems like China's tend to be characterised by strong institutional frictions, if not divides [10]. For a substantial period of time, the country's industrial structure used to be characterised by a dichotomy between a number of major players in the state-owned sector on the one hand and foreign-invested firms and a few key players in the private sector on the other [9,28,29]. While state-owned firms play a dominant role in traditional, mature industries [1], private and foreign-invested enterprises have come to dominate more modern branches like IT or telecommunication [30,31]. Although this dichotomy may no longer be as clear cut as it used to be [13,32,33], it continues to fuel different logics of developments across industries and technology fields. Depending on their institutional composition, industries and regional innovation systems are exposed to different factors of influence to different degrees and develop accordingly [32,34].

Furthermore, recent figures on patenting and financial investment in enterprise sector research and development suggest that a transformation from technology absorption and adaptation to the genuine creation of new, world market-relevant innovations in domestic firms may be imminent if not already underway [9]. Contrary to past years, where such innovations were mostly limited to single firms in specific regions, like Huawei or ZTE [28,33,35], a broader basis of internationally-relevant technological capacities appears to be emerging [36]. At the same time, it remains unclear to what extent current patenting is the result of new technological capacities, and to what extent it is triggered by political encouragement or pressure to increase domestic applications regardless of their quality [4,37] with the aim to create an image of 'indigenous' innovation.

Finally, China's industries, like those in every other country, have to respond to international technological trends [21,38,39]. While these trends drive long-term transformation and regional rearrangements on the one hand, they also form the short-term frameworks for different provinces' growth perspectives and resilience in the face of a specific sector's cyclical crisis on the other [32,23]. In concert with the aforementioned national trends, this international framework will co-determine 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.

In conclusion, a number of different dimensions have to be taken into account when analysing recent trends in the regional architecture of China's innovation system. In a first step, therefore, the following paragraphs identify key dimensions of analysis based on the existing literature. The second step presents a very brief, literature-based overview of the status quo in the regional architecture of China's innovation system and then proposes a number of research questions.

2.1. Dimensions of analysis

Based on the existing literature, four main structural attributes can be identified that are relevant for the emergence of growth trends in China's regional innovation systems. Conceptually, these have been posited in the regional science literature for more than a decade and have recently also been taken up in a number of China-specific studies.

Firstly, differences with regard to the *overall level of technological activity*. In some of China's provinces, technological activities have developed earlier and faster than in others [9,24,40]. In general, such regions are in a better position to muster the critical mass needed to build up functioning regional innovation systems or consolidate and improve existing ones [41–43]. Empirically, moreover, high levels of pre-existing technological activity were found to be closely connected with the development of relevant clusters of internationally competitive firms in Chinese provinces. Hence, the overall level of technological activity is relevant when assessing a regional system's capacity to trigger or sustain mutually reinforcing dynamics at a local level [32].

Secondly, the *relative roles of the public and the private sector.* Just like the overall level of activity, the potential for local complementarities between pre-competitive research and concrete technological development constitutes a key requirement of dynamic regional development in China [10]. As Landabaso [43], Cooke et al. [42] and Feldman/Kogler [44] have shown, a certain level of technological activity may be a necessary condition for mutually reinforcing dynamics, yet only critical mass on both sides of the spectrum will prepare the ground for genuinely self-supporting regional innovation systems. Typically, the efficacy of science-industry relations and hence their ability to trigger and fuel local technological dynamics is limited by the availability of relevant partners in the region [17,18,45,46].

Thirdly, *technological specialisation and sectoral focus*. As demonstrated many years ago in the literature, different sectors are subject to different technological and business cycles [47,48]. In particular, modern and constantly evolving fields like information technology or telecommunications are subject to short cycles, while more mature ones, like general machine building or chemistry are – as a tendency – characterised by longer cycles [32,23]. Technological specialisation in the Chinese context can be taken as a proxy for the internal structure of the patenting firm sector that dominates the regional innovation system. While some sectors are characterised by large, state-owned enterprises that are more prone to respond to political targets [4], others are characterised by private players targeting international markets [49].

Finally, *international orientation.* Right up to the present day, the question of whether a province's industries are internationally oriented remains crucial for its economic and technological development [50], even though this role cannot be considered conducive by definition [23]. In China, the question of market orientation plays a crucial role, not only for foreign-invested [51], but increasingly also for leading domestic firms [49]. While this is influenced by the different sectors' varying inclinations to internationalise [44], other factors can be equally as important. Not least, globally-oriented patent applications have to meet higher thresholds with a view to 'new to the world' criteria [52] than SIPO applications, which are still regarded as rooted in a political as much as in a technological context [4,37].

2.2. The regional architecture of China's innovation system

Regarding the status quo of the Chinese innovation system's regional architecture, earlier studies have tended to come to the following, general conclusions:

Despite documented variety among China's provinces [7,46], many consider the regional architecture of China's innovation system to be generally stable [35,8]. However, recent years have seen notable growth dynamics in some provinces, the relevance of which has yet to be fully understood [9,14].

China's technological innovation system remains dominated by a limited number of field-specific competences concentrated in a small number of internationally competitive firms [28] and it is slow to develop complementary capacities [35]. Local spillovers of foreign technological investment are often limited [23], at least outside the main technological centres [51].

For a long time, China's technological innovation system could be described as characterised by "islands of innovation" [10] in a large sea of rather uncompetitive other provinces, whose firms either could not or were not interested in matching global patenting standards [4,28]. Recently, moreover, concerns have emerged that arbitrary patent promotion policies may have worsened rather than improved this issue [37].

Finally, the literature demonstrates that Chinese regions' specialisation in specific technological activities has had implications for their further development as it defines their susceptibility to specific sectoral trends [23] while at the same time, the structure of the local industrial sector determines their susceptibility to government intervention [4,34]. Finally, regional innovation paradoxes [41] continue to be identified in many peripheral Chinese regions.

2.3. Ambition and research questions

Against this background, this paper's core contribution will be to establish to what extent there has been a departure from the aforementioned regional set-up discussed during the mid to late 2000s. In short, it seeks to establish whether the broad-based rise in China's technological capacities, which general print media have been heralding for about a decade, may now finally be taking effect and, if so, what impacts can be expected on the development of both leading and lagging provinces.

This paper examines the following four research questions:

RQ 1. can it be observed that, while China's current technological system continues to create a win-win situation for many of its already strong regions; new sectoral, technological and political trends are prompting a capacity-based catch-up of specific provinces?

RQ 2. can it be observed that, in parallel to the emergence of new, general trends at both the global and the domestic level, some aspects of the structural composition of China's provinces technological systems have changed notably?

RQ 3. can it be observed that, while China's provinces display quite distinct profiles with respect to their technological activities, these profiles are not completely idiosyncratic but can be subsumed under a number of meaningful, more general categories?

RQ 4. can it be observed that recent growth in technological activities in Chinese provinces depends on these provinces' technological profiles to a notable extent, and that an analysis of the overall system may differ from that of its emerging regions?

Before these questions are addressed in detail, the following section describes the method of data generation, treatment and analysis. Subsequently, findings and patterns are documented in line with the proposed dimensions of analysis. Finally, these findings as well as their more comprehensive implications are discussed and conclusions drawn.

3. Methodology

As outlined in the introduction, this paper focuses on providing answers to the above stated research questions using patent data analyses, rather than seeking to combine these with other information as prior studies have done [35].

Importantly, the study focuses on developments *within* the Chinese technological system and takes the Chinese market as the main point of reference. Hence, all patent applications analysed in this study are those at the Chinese State Intellectual Property Office (SIPO). 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 about specific patents' attributes needed to conduct an analysis, e. g concerning the type of applicant, international orientation or technological content, is currently not available in any usable or valid format directly from Chinese sources, but can only be retrieved from a full version of the EPO 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. As one result of this, they do not contain address information for applicants or inventors. Fortunately, however, some information on the place of application is included in SIPO raw data.

Thirdly, substantial data treatment is needed to develop classifications of technological fields, organisational types and to identify SIPO patents which have a family member abroad. Fortunately, the author's institute can draw on a substantial history of prior work in these fields, so that established and proven approaches were already available which could be applied in this study [53,54].

Consequently, the first and most crucial task when compiling a database suitable for the intended analysis was to merge specific information from Chinese raw data with a full and specifically expanded version of EPO PATSTAT. The required data on each patent's place of application was contributed by the Chinese National Library of Sciences, drawing directly on SIPO sources. Notably, location information refers to applications filed by Chinese natural and legal persons, thus explicitly excluding applicants that are legally registered outside China.

On this basis, reliable indicators could be constructed for the three above mentioned structural dimensions 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 or the private economy [55]. This routine builds on Chapter 3 of the first Frascati Manual [56], but takes into account the limitations and specificity of the available patent data. Hence, categories are defined intentionally broader than conceptually possible, but in a way that can be delineated in an empirically robust manner: university, public research institutes (forming the public sector) as well as firms and single inventors (forming the private sector).[1]

The *technological field* to which the substance of specific patents relates can be determined based on its assigned IPC codes that were

[1] PNP organisations play a limited role in the Chinese innovation system [57,26].

classified according to a proven list of nineteen technological fields [53]. This classification has been used in multiple studies over the past decades and thus provides a relevant point of reference (for China, e.g. Kroll/Schiller [33]). Moreover, it differentiates clearly into (as such) more modern and more traditional fields.

The *outward orientation and/or international relevance* of specific SIPO applications 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 also on other international markets [35,36,58]. Furthermore, international family members can be differentiated by the specific non-Chinese office where they occur, to capture the different aspects mentioned above.

Based on this comprehensive compilation of data, a more general analysis can be made of the regional architecture of the Chinese innovation system.

In a first step, a cluster analysis is conducted to identify key groups of provinces with a view to the above mentioned structural criteria, while the absolute number of activities will be taken out of the equation so as to not overly dominate the result.

In a second step, to address RQ 3, the different clusters are characterised with a view to their average structural characteristics as well as the average level of patent intensity among their member provinces.

Finally, the recent growth of patent applications is determined for the different clusters of regions during the periods 2008–10 and 2010–12, respectively. On that basis, detailed conclusions are drawn regarding RQ 4.

4. Results

The first part of the following section presents this study's empirical findings along the four main dimensions of analysis (addressing RQ 1 and 2). The second part presents the results of the further analyses needed to address RQ 3 and 4.

4.1. Level of activity

With a view to RQ 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 ranging among the nation's top ten regions (Fig. 1). More specifically, for example, Anhui's annual technological output has increased by more than 60% since 2008, while Shaanxi's has grown by close to 50% and Shandong's by around 35%. Patent applications in all the remaining provinces together (red sphere in figure) display 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 technological centres. One notable exception to this rule 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 already occupies first place in the national ranking and subsumes close to 20% of China's overall patent outputs within its boundaries. A two-pronged trend can thus be observed with regard to overall disparities. At the national level, Jiangsu's forging ahead is likely to increase the overall level of regional inequality, if only due to the region's substantial overall weight. At the same time, this effect will be compensated by the overall mitigation of disparities caused by the more convergent development among all other provinces.

As Fig. 2 clearly illustrates, the traditional pattern of technological activity in China has thus not been substantially reversed. Evidently, the overall division into strong coastal areas, China's increasingly active geographical center and a number of still largely detached peripheral regions still seems to hold. As Fig. 2 illustrates further, many inland provinces are now displaying growth rates that exceed those in established coastal areas. In line with the patterns found in Fig. 1, these differences in growth rates seem to have increased further in recent years (columns indicate growth 2008–2010 vs. growth 2010–12).

4.2. Role of regional actors (public vs. private)

In a first step to address RQ 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 studies. Nonetheless, the overall regional distribution of universities' patenting in China has experienced a stronger degree of deconcentration than

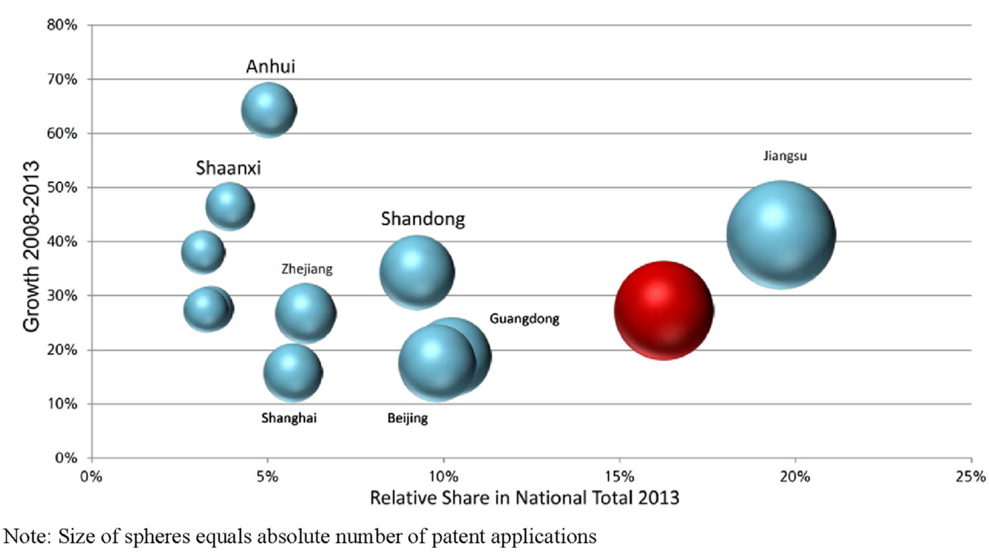

Fig. 1. Growth of Patent Applications in Chinese Provinces 2008–2013. Note: Size of spheres equals absolute number of patent applications. Red sphere indicates sum of all provinces not otherwise represented by blue spheres.
Source: Own analysis

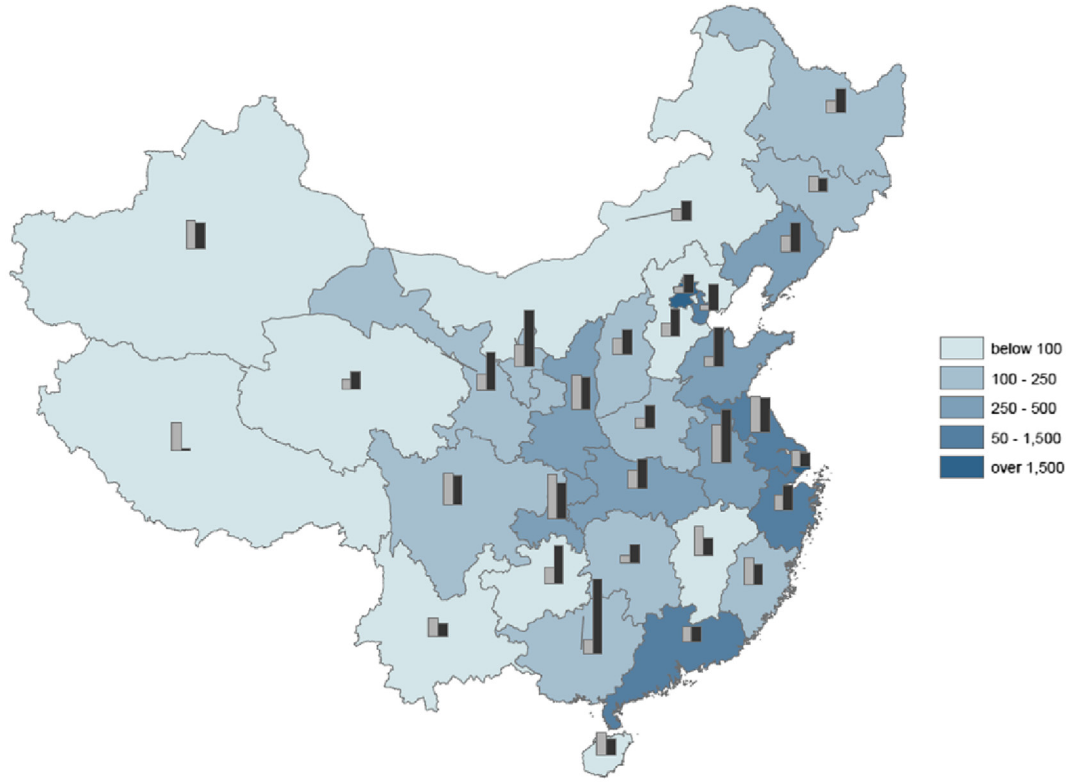

Fig. 2. Patterns of Patent Application in Chinese Provinces (Patent Intensity and Growth). Note: Grey and black columns indicate growth from 2008 to 10 and from 2010 to 12 respectively.
Source: Own analysis, Map based on ESRI ArcGIS

patenting in general. While the overall Gini-Coefficient barely changed from 62.67 in 2008 to 61.06 in 2012 (probably due to the strong influence of Jiangsu), the degree of concentration with respect to university patents decreased substantially from 61.15 (2008) to 56.96 (2012). This suggests the influence of a trend here that is less relevant for the overall innovation system, i.e. the overall economy.

Furthermore, it remains noteworthy that a high share of university patenting cannot be considered an attribute of either leading or lagging regions. Cases demonstrating the strong role of the public research sector can be found among leading (Zhejiang) as much as among emerging (Sichuan) or lagging (Gansu) regions. Likewise, university patenting can play a limited role in all three types of region (Guangdong, Anhui, Tibet). Consequently, the role of universities for the regional patterns of patent application can be interpreted as a general and largely independent characteristic of a regional technological system that neither pre-determines that system's success or failure, nor provides evidence that success or failure has already taken place in a province. 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 promotion.

4.3. Technological specialisation and sectoral focus

In a second step to address RQ 2, the analysis reveals a mixed picture with respect to technological specialisation. As a tendency, regional disparities of activity tend to be higher in 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.

As an example, the following paragraph briefly discusses regional patterns in specific technological fields. Furthermore, Figs. 3 and 4 illustrate the distribution of patent activities in the field of telecommunication, in which activities remain strongly concentrated on Beijing, Guangdong and a few other coastal provinces. Currently, the telecommunication sector displays the strongest regional concentration of all fields and remains concentrated in leading regions in both absolute and relative terms. The regional distribution of applications in the field of general machinery also displays notable disparities but these are by no means as strong as for telecommunication. While, in absolute terms, most activities remain concentrated along the coastline, a number of inland provinces are specialising in relative terms. For pharmaceutical patent applications, it seems that high specialisation in this field is indeed tantamount to being an indicator of technological backwardness - even when probable special effects of 'Traditional Tibetan Medicine' are taken out of the equation (Fig. 4). Consequently, the degree of regional concentration of technological activities is lowest in the pharmaceutical sector.

As established in the literature, different sectors have different technological cycles, trends and framework conditions [59,60], so that pronounced specialisation in certain technological fields may render some regions more receptive to specific global trends than

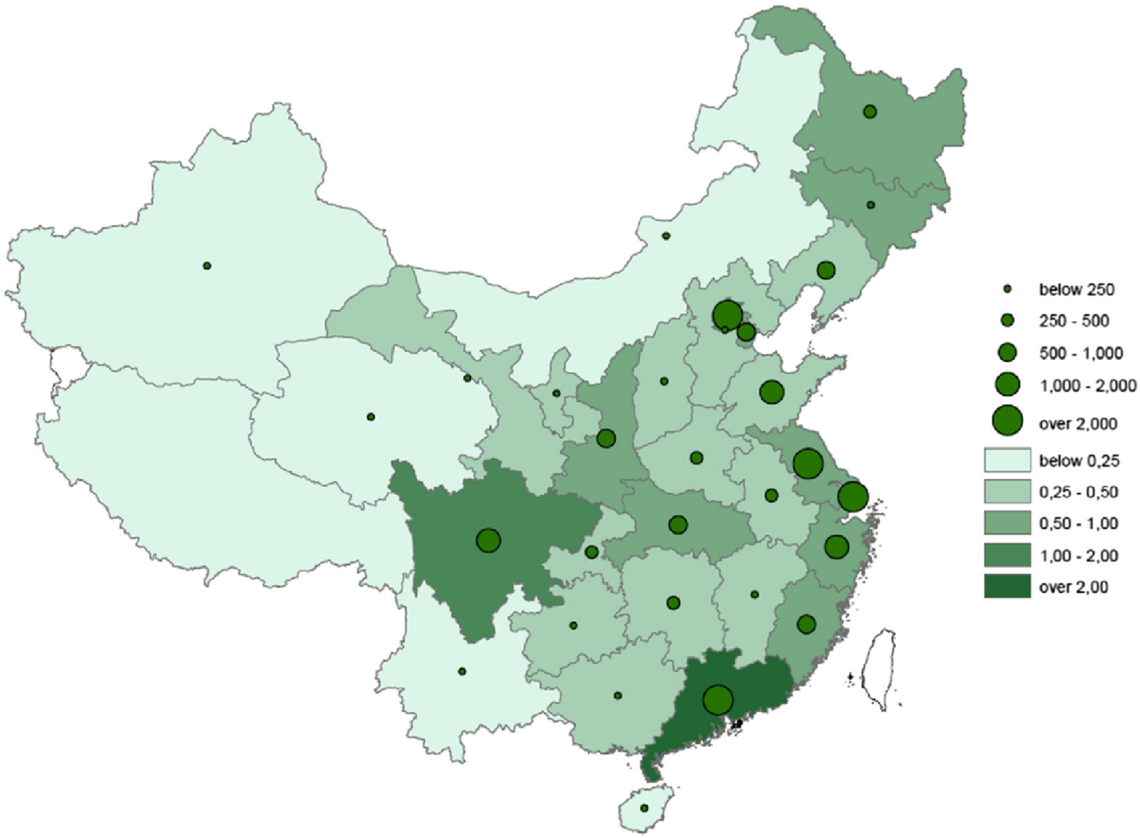

Fig. 3. Regional concentration and specialisation of Chinese patent applications in the field of telecommunications (absolute number and location quotient).
Source: Own analysis, Map based on ESRI ArcGIS

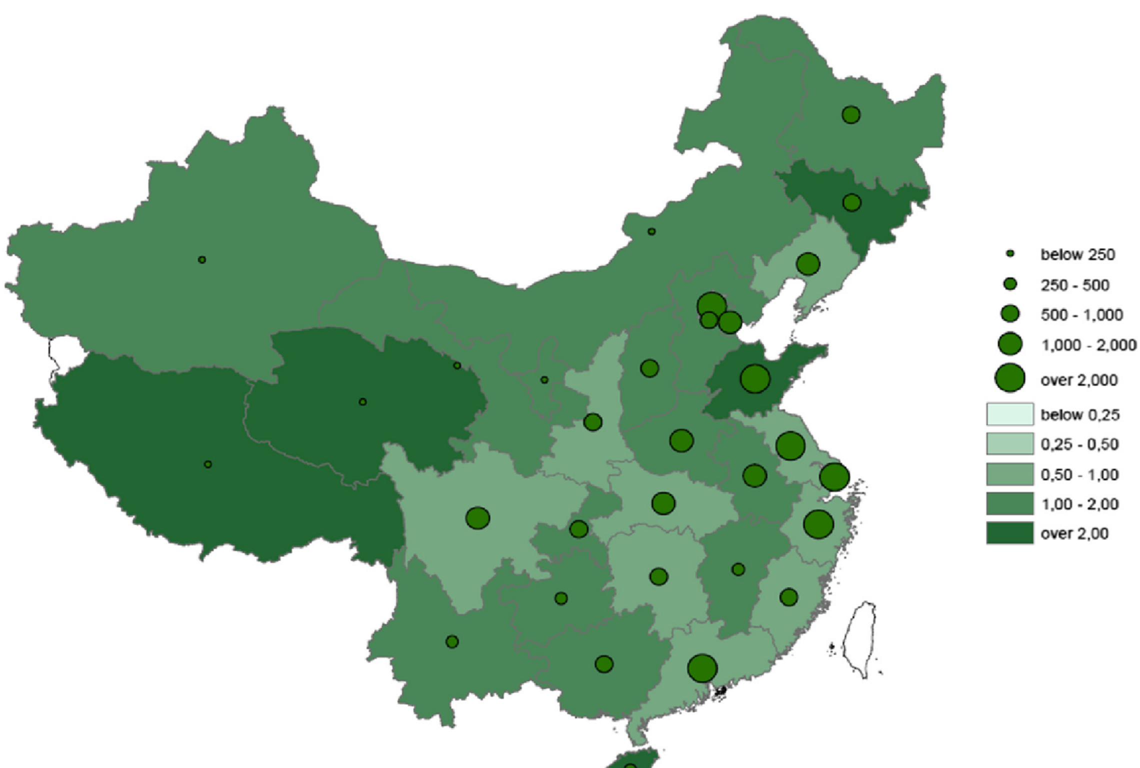

Fig. 4. Regional concentration and specialisation of Chinese patent applications in the field of pharmaceuticals (absolute number and location quotient).
Source: Own analysis, Map based on ESRI ArcGIS

others. Moreover, as the Chinese government continues to favour specific lead industries and indigenous innovation [15], mostly state-owned industries may be subject to other aspects of national industrial support policies than largely private and/or foreign-owned sectors of the industrial economy. Finally, different industrial sectors will respond differently to changes in the availability of specialist human capital or to simple changes in labour costs. While some 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 in different technological fields. While such an analysis cannot reveal the exact reasons for specific trends in single sectors, it can try to indicate the underlying logic of change by comparing sector-specific developments.

In summary, the analysis illustrated in Table 1 finds that modern, internationally-oriented, and largely privately-dominated sectors tend to display a notable trend 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, or indistinct other activities (textiles etc.) display a slight trend towards concentration. While the exact reasons for these trends must remain unknown, it appears logical to assume that Table 1 reflects some capacities in 'modern' industries moving further inland, and an extension of activities beyond the formerly small group of key applicants from Guangdong. At the same time, we may be seeing a process of regional clustering in more traditional industries as they modernise internally and become more dependent on specific regional sources and pools of knowledge.

4.4. Outward orientation and international relevance of patenting

In the third and final step to address RQ 2, this study analysed the international relevance of patent applications 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 been produced by a much smaller group of leading institutions and, as a result been geographically much more concentrated than technological activities in general. Throughout the past decade, the basis for this concentration has been the fact that most firms and research institutions with international orientation and strong technological capacities were located in the three main areas of Beijing, Guangdong, and Greater Shanghai. It was also indirectly a result of the fact that these provinces display specialisations and host lead firms in the ICT and telecommunication industries, where most of the globally relevant technological capacities in China's industry remain concentrated [28].

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 that of total patenting in even the most concentrated sectors. Overall, the analysis finds that the regional distribution of relevant patent applications has not changed substantially in recent years. More precisely, the Gini coefficient of regional concentration decreased only very moderately from 83.98 (2008) to 82.68 (2012). However, this should not obscure the fact that internationally relevant patenting has increased substantially in a number of inland provinces. 5 years ago, only Guangdong exceeded a share of 10% transferred patents in total SIPO applications, a situation that is now found in four provinces. Moreover, the absolute extent of activities has increased substantially in the greater Shanghai area and parts of 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 (which may well be mostly considered evidence of foreign-invested companies' activities) and of transfers to the World Intellectual Property Office (WIPO), which are with greater likelihood related to internationally relevant and/or qualitatively more robust inventions of domestic Chinese firms (cf. Fig. 5). As an example, parallel applications at the Taiwanese office are illustrated in Fig. 6.

4.5. A classification of Chinese Region's technological systems

In preparation for addressing RQ 3 and taking note of the diversity of patterns and trends documented above, a centroid-based cluster analysis was conducted to aggregate China's provinces in meaningful groups according to their local patterns of patenting. This analysis was conducted using standard SPSS procedures and based on the following variables:

- Share of university patenting in overall patenting
- Location quotient of 19 key technological fields (ISI19)
- Share of applications at four different international patent offices including WIPO.

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

If the number of desired clusters is set to four, the analysis results in two 'leading clusters' of Beijing and Guangdong as well as of Shanghai and Jiangsu, one cluster of emerging provinces in Central China and one cluster of peripheral regions in Western China. This replicates the standard assumptions with regard to the regional structure of the Chinese innovation system [9,33]. If the number of desired clusters is set to six, the overall framework remains the same, while both the emerging and the peripheral cluster split up further into two clusters each (3&4; 1&5 in Fig. 7), underlining the validity of the basic structure yet adding further differentiation (Fig. 7). Increasing the number of clusters to eight does not produce a new structure but simply splits the two 'leading clusters' into

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

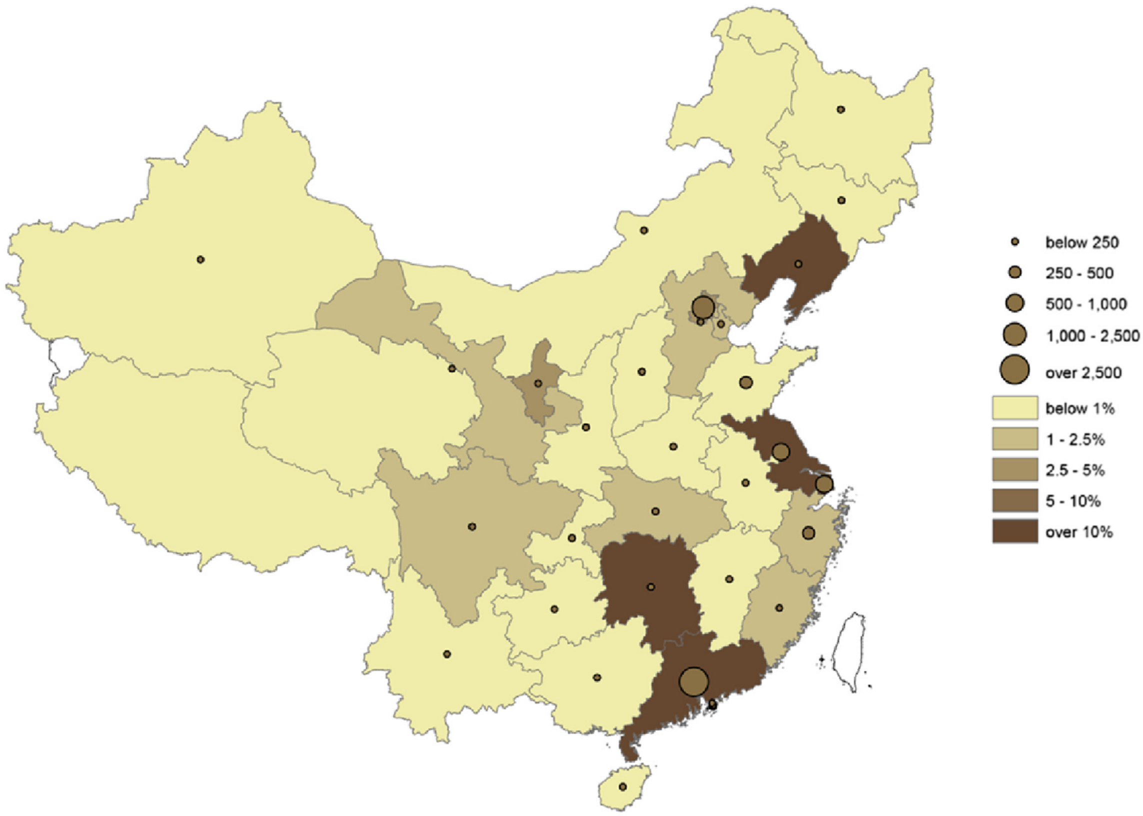

Fig. 5. Share and Amount of SIPO Patents which have been transferred to WIPO via PCT (2012).
Source: Own analysis, Map based on ESRI ArcGIS

Fig. 6. Share and amount of SIPO patents with family members at the Taiwanese patent office.
Source: Own analysis, Map based on ESRI ArcGIS

Fig. 7. Classification of provincial technological systems into six clusters.
Source: Own analysis, Map based on ESRI ArcGIS

their constitutive provinces.

Intentionally, neither the absolute nor any relative level of patent activity was included in the structural cluster analysis. Nonetheless, a very simple measure of patent intensity (patents per inhabitant) is included in the following description of clusters to distinguish technological hotspots and lagging regions.

With regard to the constitutive characteristics of the individual clusters in a system of six, Table 2 illustrates that leading Cluster 1 (Shanghai and Jiangsu) is characterised by a strong outward orientation, a broad technological basis (with a focus on electronics) and a notable regional share of university patterns. Leading Cluster 2 (Beijing and Guangdong) is different in that the regional technological profile is more focused on IT and telecommunication and 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 university patenting in overall applications is somewhat lower. The patent intensities in both clusters substantially exceed the national average with 1475 (Cluster 1) and 1559 (Cluster 2) applications per million inhabitants.

When looking at the emerging 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). Cluster 3 still displays a certain (even if low) international orientation of technological activities, but this is notably lower in Cluster 4. At the same time, those provinces with relatively more pronounced technological activities in the higher education sector record some application activities in 'modern' fields such as IT or telecommunication, which remain largely absent in the more business- and outward-oriented group, that focuses on traditional fields. With regard to overall patent intensity, both clusters reach about one sixth to one fifth of the leading clusters' provinces (Cluster 3: 330, Cluster 4: 248). In the following, this differentiation will be used to analyse internal differences within the group of emerging 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.

Table 2
Characteristics of the six clusters.

	Role of public sector	Outward orientation	Technological focus
Cluster 6	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 1	Hardly any University Patents	No Outward Orientation	Pharma, Textiles, some Chemicals

Source: Own analysis

With regard to the clusters of peripheral regions, the arguably largest difference between them is the overall level of patent intensity that reaches 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.

4.6. Technological systems' characteristics and technological growth

In preparation for addressing RQ 4, this final subchapter of the results section explores the relation between specific characteristics of Chinese provinces' technological systems and the overall growth in SIPO patent applications that could be observed in the periods from 2008 to 10 and 2010–12, respectively.

A two-stage strategy is pursued:

Firstly, a backward stepwise regression is conducted with overall patent growth between 2008–10 and 2010–12 as dependent variables, the relation of international family members to the total number of SIPO applications and the share of university patents in such applications as the main explanatory variables, while, at the same time, controlling for sectoral or field-specific structures by including the location quotients of all 'ISI19' technology fields. To add robustness to the analysis, the stepwise regression models are compared with the respective complete models that include all variables simultaneously.

Secondly, growth rates from 2008 to 10 and 2010–12, respectively, are determined and analysed separately by cluster. Considering the continued dominance of some major provinces (mostly the four subsumed in the 'leading clusters'), the results of overall models are likely to be dominated by developments in these regions. Against this background, a cluster-based analysis appears suitable to explore additional differences *among* emerging regions.

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

As illustrated in Table 3, the first approach yields the finding that there has been a structural change between the growth observed from 2008 to 10 and the growth prevalent in the two years after. Between 2008 and 2010, outward orientation was strongly and positively correlated with growth. This probably reflected a situation in which regions with a strong degree of foreign investment or the headquarters of outstanding national firms reinforced 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. These findings are clearly revealed when following a stepwise regression approach (cf. Table 3) and remain discernible at the 0.10 level when all variables are entered simultaneously. In the subsequent period from 2010 to 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 a factor significantly associated with overall growth in SIPO applications at the 0.10 level. Additionally, different technological control variables were significant in each period with only one overlap: the negative association of a specialisation in general machinery with growth. A full regression into which all variables are entered simultaneously does not yield any significant results for the second period.

Overall, the findings for the first period reflect the positive influence of international orientation. In computer technology and audio-visual electronics, the analysis finds growth associated with fields that display a strong outward orientation, while specialisations in domestically-oriented fields like chemicals or general machinery have a negative influence. One exception to this rule is the negative influence of telecommunication technologies, possibly reflecting the relative decrease in growth in the already dominant Beijing and Guangdong. For the 2010–12 period, in contrast, no such intuitively logical pattern results. The only type of specialisation that is positively associated with growth is that in machine-tools, whereas a somewhat incoherent group of pharmaceuticals, measurement and control technologies, optics, non-polymer materials and medical equipments display a negative association. In summary, the trends during the second period are more complex, and a novel pattern has not yet emerged as the overall insignificant simultaneous regression suggests.

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 with the effect 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 reflect an increase of low-quality (internationally not relevant) patenting in response to political target setting, which is associated with public players like universities as these are more likely to translate targets directly than foreign-invested or domestic, world market-oriented technology firms.

As illustrated in Table 4 the second approach yields even more differentiated insights. During the period 2008–2010, differences in growth were not significant in terms of an overall F-statistic. In

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

	Cluster 6	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 1	F	p Value
2008–2010								
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								
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

terms of cluster-specific averages, a certain downward trend could be identified for the leading provinces in Cluster 2 (Beijing, Guangdong), and a certain upward trend for the emerging regions in Cluster 4 (those with a strong university basis). Overall, however, variation within the groups was too high to make these differences significant. During the period 2010–2012, in contrast, technological growth differences between clusters became significant in terms of F-statistics: a strong upward trend of the emerging regions of Cluster 3 (those without a strong university basis and focused on traditional industries) and a notable downward trend of the genuine periphery (Cluster 6). At the same time, former growth differences between leading regions were somewhat mitigated.

Interestingly, the regional structure growth patterns among emerging regions clearly differ from the general trend identified in the regression model. Contrary to the overall picture, a high share of university patenting was not conducive to increased growth among emerging provinces. Instead, regions like Zhejiang, Anhui, Shandong, and Guangxi became part of the catching-up process to a greater extent. At the same time, this does not mean 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 if it did not increase moderately. Consequently, the absolute contribution of such provinces to technological growth and convergence still eclipses that of smaller, more business-oriented 'Cluster 4' regions.

This section's 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 even today mostly rely on mature, less world market-oriented industries. At the same time, there is no reason to assume that all the industrial sectors of these provinces are more state-oriented than others and thus by definition more receptive and responsive to political target setting (quite the contrary, for example, would appear likely in Zhejiang and Shandong). Hence, political pressure alone does not naturally explain these findings.

5. Discussion

With a view to this paper's research questions, the following findings can be reported:

Firstly, the most recent development of China's technological system gives no indication that substantial mitigation of the notable geographical disparities with regard to technological capacities appears imminent, confirming the findings of both earlier and more recent studies using secondary statistics on expenditure and employment [9,28]. While there is notable evidence of an absolute strengthening of many non-coastal regions' positions, the continued dynamic of the Greater Shanghai region in particular precludes a general decrease of disparity.

Secondly, the pattern of technological specialisation among Chinese provinces has remained mostly stable over the past five to ten years. As predicted [44], the fact that China has become globally competitive in only a few technological fields continues to create an imbalance favouring regions with these specialisations. Structurally, this situation will be difficult to amend. Nonetheless, the formerly extreme localisation of world market-oriented capacities in some fields [28] seems to be waning as the result of technological capabilities spreading across more relevant actors than before. Resonating with publications on China's most recent patent policies [37,4], the degree of concentration of university patents has decreased substantially as actions and policies supporting technological transfer, formerly limited to the 'islands of innovation', 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 it continues to rise in the leading regions), it has nonetheless increased substantially in both absolute and relative terms in a number of inland provinces.

Thirdly, China's provinces can indeed be divided 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 emerging regions. The well known differentiation between Beijing, Greater Shanghai and Guangdong's Pearl River Delta can thus meaningfully be complemented by a classification those provinces that rank around national average.

Fourthly, there is indeed a notable influence of the aforementioned regional characteristics on the most recent developments in Chinese provinces. More importantly, there is evidence of a structural change here that corresponds to the latest surge in Chinese patenting, which many outside observers argue to be at least partially politically induced. In the overall system, the public sector plays a positive role with respect to further growth. At the same time, the opposite holds true for the most recent developments in emerging 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 remains remarkable to see undeniable changes in the association in growth and structure coincide with a time in which a new major political initiative towards 'indigenous innovation' can be expected to have taken hold. While it remains unclear whether the newly emerging correlation of growth with a strong role of the public sector implies that the patents responsible for growth actually originate from universities, it is notable that growth is occurring within those frameworks considered to be more responsive to political target setting. This impression is anecdotally backed by the fact that patenting grew substantially in central government-oriented Beijing (8% vs. 25%), while it remained comparatively stable in the more central government-averse regions of Guangdong (21% vs. 22%) and Shanghai (21% vs. 19%).

At the same time, there seems to be a different logic of technological growth in emerging provinces. Among them, the lead is now 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 new policies requesting that even these provinces contribute to the nation's new push towards 'indigenous innovation' irrespective of their 'true' technological capacity. The fact that many of them still display very low rates of patents with international relevance could be considered evidence of this. On the other hand, it could be argued that the findings may indeed reflect if not increasing technological activity then an increasing acknowledgement that, e.g. even incrementally improved, mature products for the domestic market can and should now be protected by patenting. Beyond the general fact that more and more experts are suggesting that the Chinese IPR system has become substantially more robust in recent years, this argument could be backed by this study's finding that some more traditional sectors are concentrating geographically, which is typically also secondary evidence of a 'real' change in the role that technology and inventions play for the production process.

In summary, this study has revealed 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 of 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. At the aggregate level of provinces, new players are entering the stage, while traditional incumbents are reinforcing and improving their position as leaders. Even though the overall framework of regional disparities remains the same, some notable rearrangements can be observed. The past few years have indeed seen a significant shift in relevant trends which are now gradually becoming visible in aggregated data.

As the analyses presented in this paper strongly suggest, however, existing structures define the reference framework and leverage points for future growth. While the effectiveness of each new trend and newly launched policy depends on the existing structure, it will at the same time have a lasting impact on provinces' relative position to each other and thus change the foundations of future developments. Structurally, however, any short-term sea change in the regional architecture of China's innovation system can be ruled out.

In line with earlier studies, this research also found evidence that there is ample reason to doubt whether the current growth of Chinese patent applications genuinely reflects increasing technological capabilities. Based on what we believe to know about the technological capacities of the emerging provinces under study, many of their apparent inventions may be politically engineered or at least encouraged.

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

Hence, it may well be that while inventors in emerging 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, then, with strengthened capabilities, they may well be in a position to exploit that knowledge. Overall, the author 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 well be considered 'real' and worthy of external observers' attention.

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