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Putting China in perspective: a comparative exploration of the ascent of the Chinese knowledge economy

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Putting China in perspective: a comparative exploration of the ascent of the Chinese knowledge economy

Abstract: This paper traces the ascent of China from knowledge economy laggard to world leader over the last two decades using a comparative perspective. Chinese trends in R&D and patenting are compared to those of the countries of the 'triad' (the European Union, Japan, and the US), as well as to those of other large emerging economies (Brazil, India, Mexico, and South Africa). The analysis demonstrates how both in innovation inputs and outputs China reflects an innovation reality closer to that of the most developed areas of the world than to that of other emerging countries. However, the rapid ascent of Chinese innovation has generated a distinct set of territorial dynamics, with innovation much more geographically concentrated than elsewhere in the world and more reliant on agglomeration forces than on more traditional 'innovative' drivers. Such a distinct geography of innovation may have until now facilitated the innovation surge in China, but poses serious future risks in terms of the sustainability of the system.

Keywords: Innovation, knowledge economy, R&D, patenting, regions, China

JEL Codes: O32, R11

Introduction

The global geography of world innovation has evolved tremendously in recent years. The most notable of the changes, perhaps, relates to the increasingly substantial contributions of the developing world to both the generation of knowledge and the production of innovation. A variety of emerging countries are assuming increasingly prominent roles in a domain that was dominated the world's most advanced economies and, most notably, by the 'triad' – the United States (US), the European Union (EU), and Japan (Furman and Hayes, 2004; Dosi et al., 2006). China is at the forefront of this global transformation and is establishing itself as one of the knowledge and innovation hubs of the world.

The ascent of new innovation players, in general, and China's rise to prominence, in particular, have, attracted considerable scholarly attention. An ever-expanding body of literature that explores innovation in China from a range of perspectives (e.g. Sun, 2003; Popkin and Iyengar, 2007; Wang and Lin, 2008; Fu, 2008; Liu and Sun, 2009; Sun and Liu, 2010; Crescenzi et al., 2012) has emerged in recent years. It is our intention to enrich the existing stock of literature by providing a comparative perspective on both the evolution of the Chinese knowledge economy and the subnational dynamics underpinning its innovation system. The aims of this research are twofold.

First, we explore the evolution of the Chinese knowledge economy via a comparative taxonomic analysis of research and development ('R&D') expenditure and innovative output over the past two decades. Second, we compare the factors that govern processes and shape territorial patterns of innovation in China to those of two members of the 'triad' (the European Union and the United States), as well as to those of two leading emerging economies (India and Mexico). The comparison is conducted via a review and synthesis of previous empirical literature. The primary aim in doing so is to highlight the heterogeneity of countries' respective innovation systems and the uniqueness of China's territorial system of innovation in particular.

The paper will proceed as follows: *Section 2* illustrates and analyses trends in R&D expenditure and innovative output in China. *Section 3* provides a spatial perspective on innovation in China, focusing specifically on the territorial concentration of innovation. *Section 4* delves into the factors that shape processes of regional innovation in China and the four other countries considered. *Section 5* concludes by forwarding two related policy implications derived from the conclusions formed in the sections that precede it.

The ascent of the Chinese knowledge and innovation economy

In order to develop a comprehensive understanding of the evolution of the Chinese science and technology system and grasp China's rapid ascent in the global innovation economy two related dimensions are considered. The first dimension relates to knowledge economy 'inputs', and to changes in R&D expenditure in particular. While not the only input to the innovation process, investment in R&D is a central determinant of an economy's capacity to both *generate* economically useful knowledge (e.g. Audretsch and Feldman, 2004) as well as *absorb*, *assimilate*, and *exploit* externally generated knowledge and innovations (e.g. Cohen and Levinthal, 1990; Maurseth and Verspagen, 2002; Griffith et al., 2003). The second dimension focuses on innovative outputs, which are perhaps the most direct reflection of a country's overall innovativeness. Innovative output – proxied here by patent statistics, an imperfect but useful and easily comparable indicator of the introduction of commercially viable innovations[1] – is indicative of an economy's capacity to do more than merely generate basic or purely scientific knowledge. It reflects an economy's facility for mobilising that knowledge and generating applied innovations.

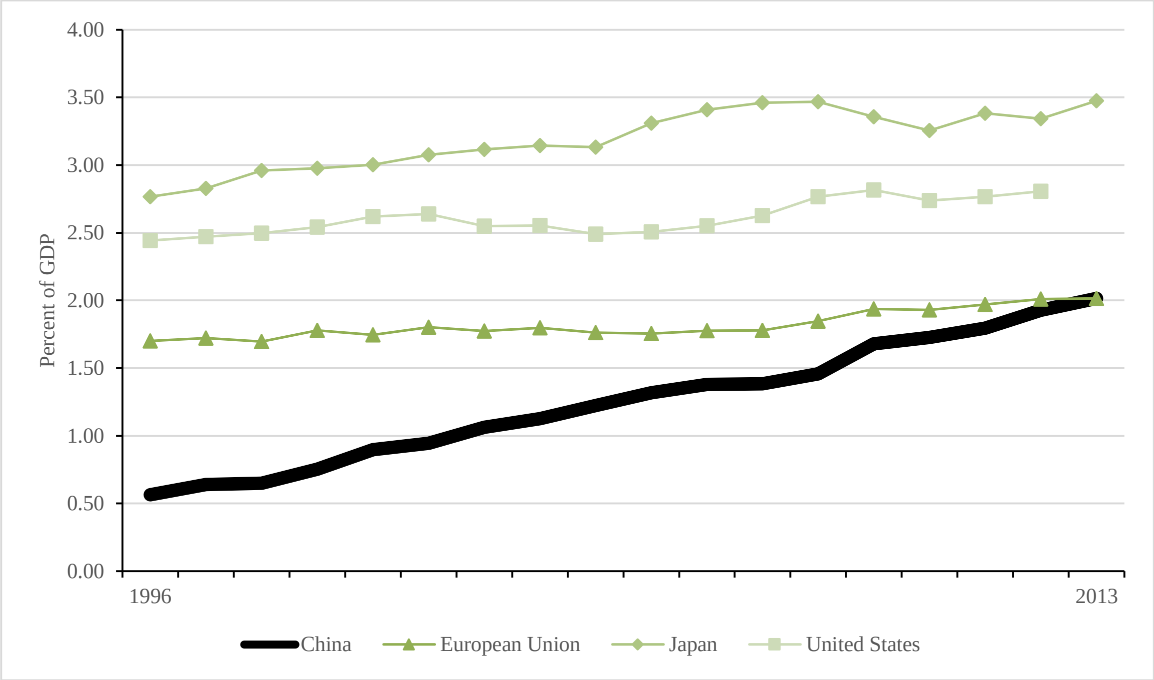
Innovation inputs: R&D in China

The Chinese R&D effort has increased considerably over the past two decades. Between 1996 and 2013, for example, Chinese investment in R&D as a percentage of GDP rose from 0.57% to 2.01% (Figure 1). This rapid increase in China's financial commitment to knowledge generation has, in fact, led to a dramatic reduction in the once prominent aggregate R&D expenditure gap between it and much of the developed world. As of 2013, relative levels of R&D expenditure in China still lagged behind those of

[1] Patent statistics are not a perfect proxy for innovative capacity. A fraction of all innovations is patented (Desrochers, 1998:57-58) and patent applications statistics are unable to reflect the novelty, utility, or value of patents for which there is conceivably considerable variation (Trajtenberg, 1990a). Patent statistics are, however, an "observable manifestation of inventive activity with a well-grounded claim for universality" (Trajtenberg, 1990b:183) and are sufficiently indicative of innovative capacity for the purposes of this taxonomic analysis. Moreover, they are the only indicator of innovation which is both available at subnational level in China and for comparable territorial units in the other countries considered in this analysis.

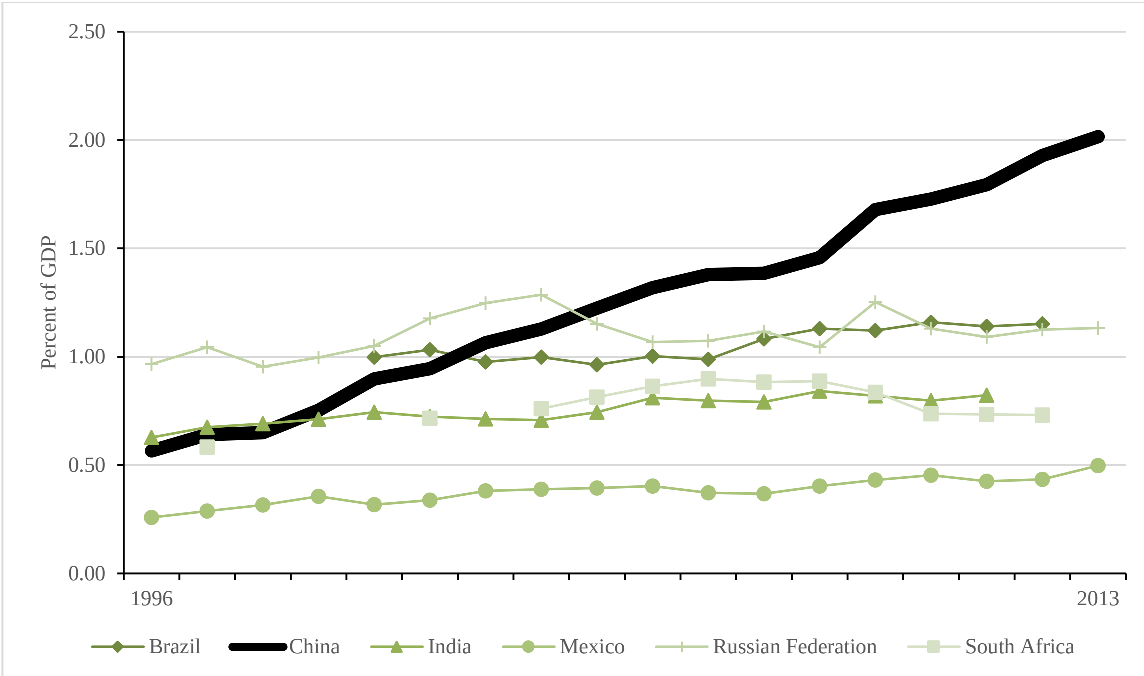
Japan (3.47% of GDP in 2013) and the United States (2.81%, 2012), but were on par with the EU (2.02%, 2013) (Figure 1).

Figure 1: Aggregate R&D expenditure in 'the triad' and China, 1996-2013



Authors' elaboration, Source: World Bank

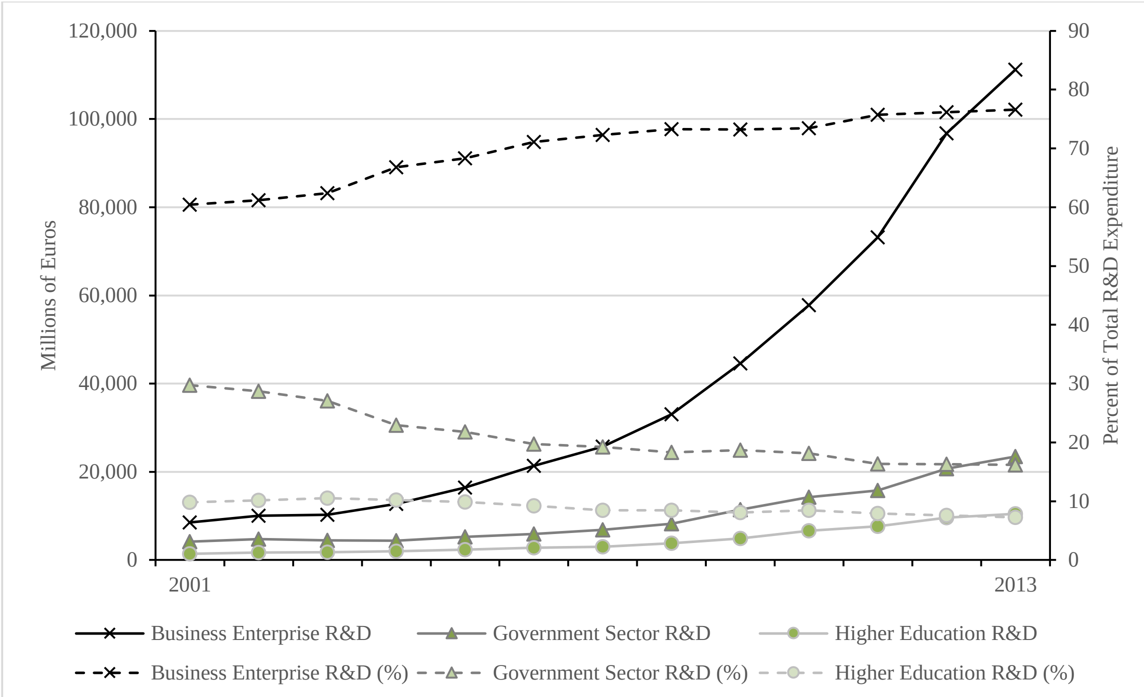
Figure 2: Aggregate R&D expenditure in Brazil, Russia, India, South Africa, Mexico and China, 1996-2013



Authors' elaboration, Source: World Bank

The recent R&D surge has also propelled China well past other leading emerging economies including, most notably, Mexico and the oft-discussed BRICS (Figure 2). In fact a considerable gap in relative R&D expenditure has emerged between China (2.01% of GDP) and other large emerging economies – Brazil (1.15%, 2012), Russia (1.13%, 2013), India (0.82%, 2011), South Africa (0.73%, 2012), and Mexico (0.50%, 2013) (Figure 2).

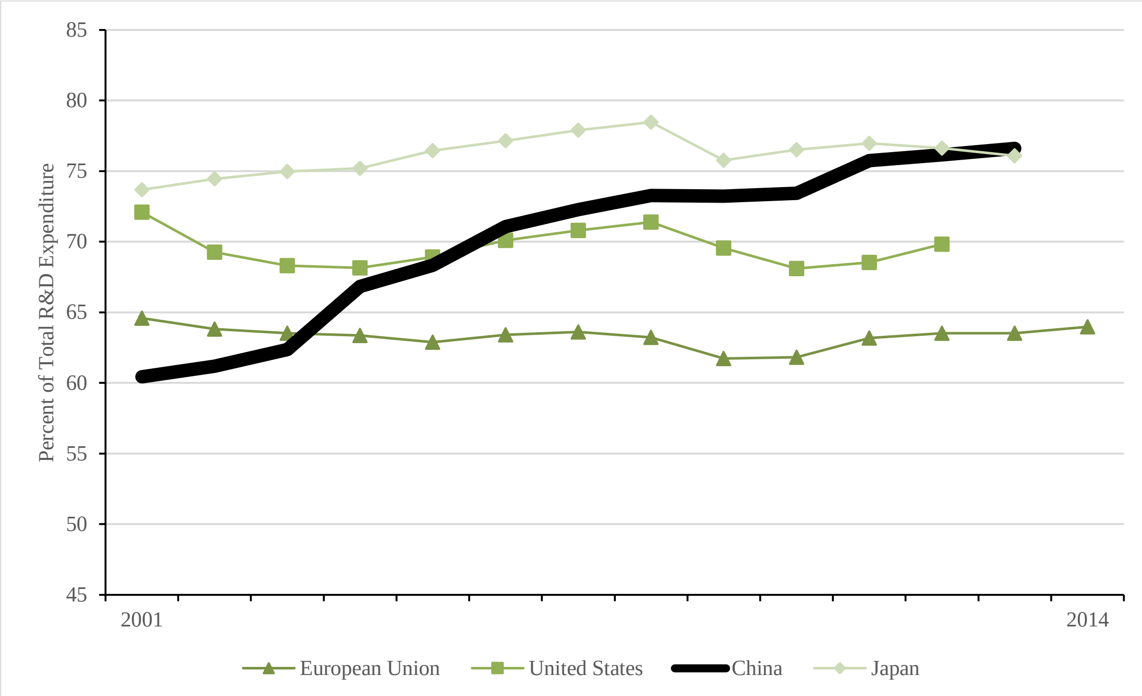
Figure 3: Sectoral composition of R&D expenditure in China, 2001-2013



Authors' elaboration, Source: EuroStat

Figure 3 disaggregates Chinese R&D expenditure and depicts expenditure trends in the Chinese business enterprise, higher education and government sectors, respectively. Private R&D expenditure accounts for not only the largest, but also an increasing share of China's total R&D spending. In 2013, business enterprise R&D expenditure accounted for 76.61% of total expenditure, up from 60.44% in 2001. Investment in both higher education and government R&D, on the other hand, declined in relative terms over the 13 year period to 7.23% and 16.16%, respectively.

Figure 4: Private R&D expenditure as a percentage of total R&D expenditure in 'the triad' and China, 2001-2014



Authors' elaboration, Source: EuroStat

China's R&D expenditure profile has evolved in recent years to mirror that of the United States and, to an even greater extent, Japan. The vast majority of total investment in R&D in the US (69.83% of aggregate R&D in 2012), Japan (76.09% in 2013), and now China (76.61% in 2013) comes from private firms (Figure 4). In these three countries, public R&D spending accounts for a relatively small share of economy-wide R&D expenditure. The Chinese R&D profile stands in contrast to that of EU. In the EU, only 63.97% of total R&D expenditure in 2014 was attributable to firms (Figure 4). Public R&D expenditure, on the other hand, figures more prominently in Europe (35.21% in 2014).

Public R&D expenditure[2] is, as Guellec and Van Pottelsberghe de la Potterie (2004:356) observed, more commonly associated with advances in "scientific, basic knowledge and [public missions]" and the maintenance and expansion of the "stock of knowledge available for the society". Private, or business R&D expenditure, on the other hand, is more readily linked to the generation of "new goods and services, [with] higher quality of output and new production processes". It is therefore anticipated that the American, Japanese, and Chinese R&D profiles – none of which suffer from shortages in public R&D investment – may be thought of as more favourable for the generation of innovative output and the development of innovative capacity more broadly.

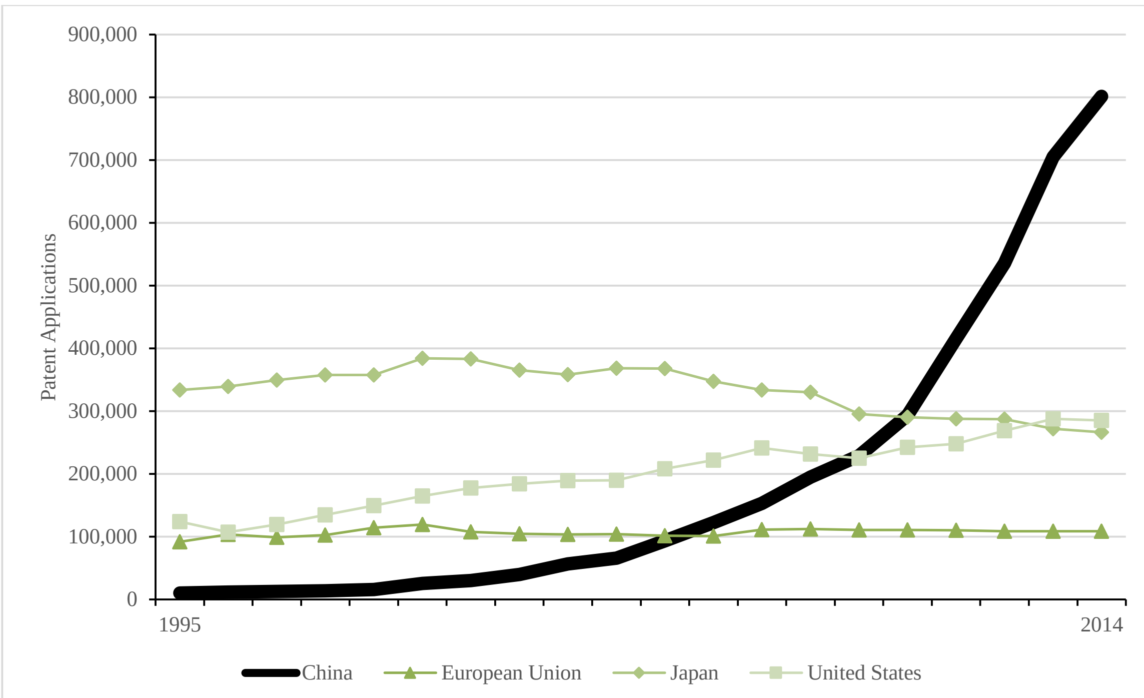
Innovation outputs: patenting

While R&D expenditure statistics provide valuable insight into an economy's commitment to the generation of new knowledge, they fail to disclose the extent to which it is capable of mobilising that knowledge. It is generally accepted that territories vary in their ability to transform knowledge generated via domestic R&D activities or otherwise into innovative output. The EU and its peripheral regions in particular, for example, have encountered challenges in converting a substantial and concerted R&D drive into tangible innovation, and in turn into economic growth and development (Rodríguez-Pose and Wilkie, forthcoming). The US, on the other hand, is perceived to be more capable of assimilating and applying knowledge, as evidenced by the innovation gap between the US and the EU (e.g. van Vught, 2004; Crescenzi et al., 2007; van Ark et al., 2008;

[2] Public R&D spending may be further disaggregated into "higher education research and development expenditure" and "research and development expenditures made by the government".

Roeger et al., 2010). An analysis of trends in patenting provides cursory, but valuable insight into both China's relative capacity to transform investment in R&D and the scientific knowledge it yields into applied, commercially viable innovation and into China's overall innovativeness more generally.

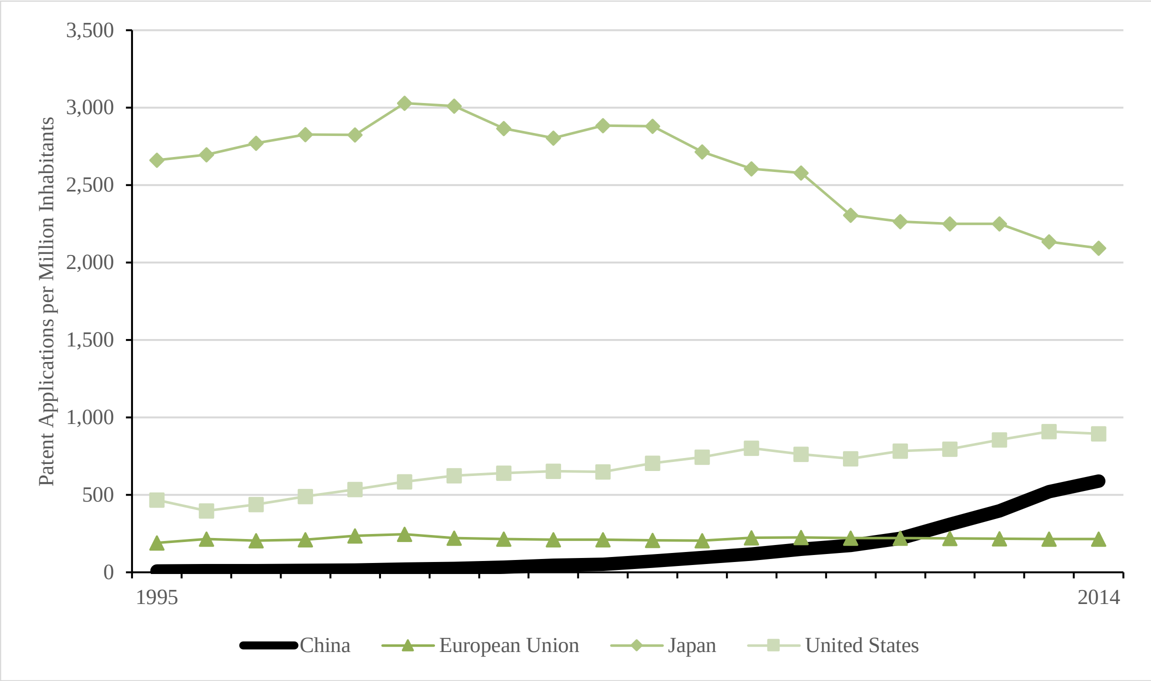
Figure 5: Patent Applications in 'the triad' and China (Absolute), 1995-2014



Authors' elaboration, Source: World Bank/WIPO

The increase in Chinese R&D investment has coincided with an even greater increase in patenting activity. In absolute terms, Chinese patent applications increased from 10,011 to 801,135 between 1995 and 2014 (Figure 5). This increase has had a profound effect on China's standing relative to other innovative economies. At the beginning of the period of analysis, China lagged well behind the US, Japan, and the EU in terms of absolute innovative output. In just short of two decades, however, China has managed to not only close this gap, but actually to open up a considerable advantage over 'the triad' (Figure 5).

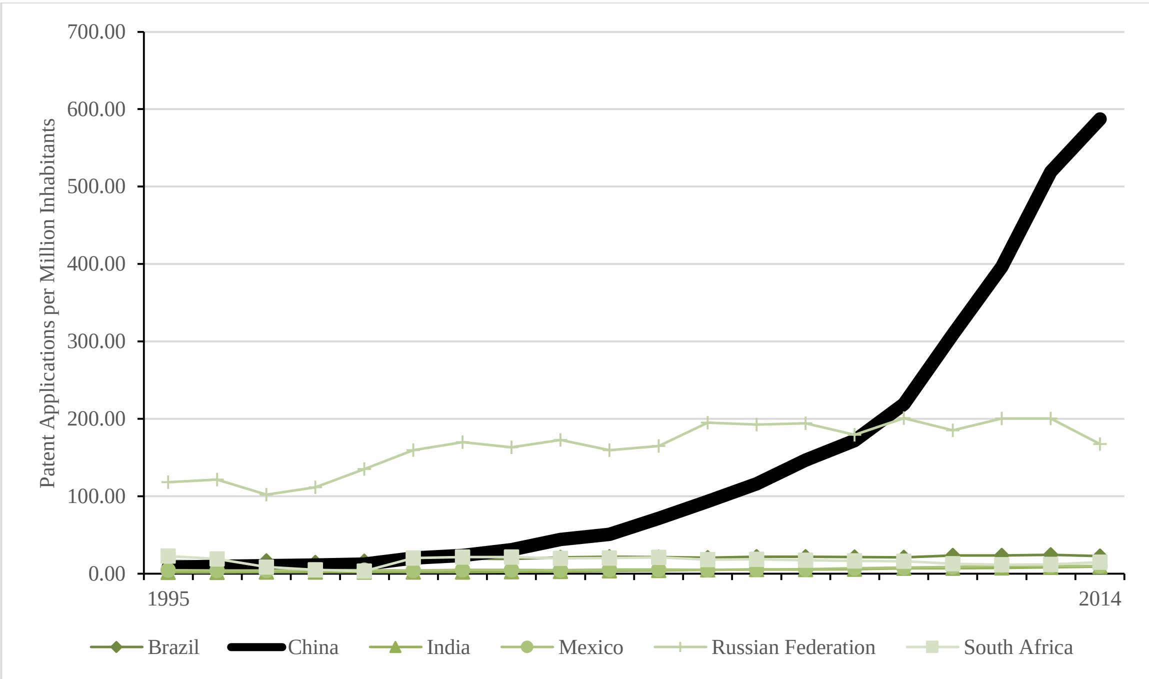
Figure 6: Patent Applications in 'the triad' and China (per million inhabitants), 1995-2014



Authors' elaboration, Source: World Bank/WIPO

While this leadership in innovation outputs is not reflected in relative terms, the increase in Chinese patenting per million inhabitants is equally evident. The innovative output gap, however, between Japan and the US, on the one hand, and China, on the other is still considerable. Patent applications per million inhabitants in China increased from 8.31 in 1995 to 587.23 in 2014 – still well below the US' 894.12 applications and considerably less than Japan's 2091.99 (Figure 6). China did however recently surpass the EU in terms of relative innovative output – in 2011, China's 309.37 patent applications per million inhabitants exceeded, for the first time, the European Union's 217.50 (Figure 6).

Figure 7: Patent Applications in Brazil, Russia, India, South Africa, Mexico and China, (per million inhabitants), 1995-2014



Authors' elaboration, Source: World Bank/WIPO

China is now the clear leader among emerging economies in both absolute and relative innovative output. In 2014, for example, China's 801,135 patent applications dwarfed Russia's 24,072, India's 12,040, Brazil's 4,659, and Mexico's 1,246. The same trends are evident in relative terms as well (Figure 7).

China's standing amongst the world's most innovative economies finds further confirmation in a brief, yet revealing investigation of two other cursory indicators –

payments received for the use of intellectual property and the prominence of high-technology exports in China's trade profile.

Payments received for the use of intellectual property provide insight into foreign use of intellectual property and are, in that respect, a useful indicator of the integration of China into the global innovation economy. Between 2005 and 2014, these payments to China increased massively from US$157.4M to US$676.4M. While the payments received by 'the triad' economies still exceed those received by China, China is rapidly catching-up to the leaders in terms of the foreign application of its intellectual property.

The prominence of high-technology exports in a country's trade profile offers further insight into its innovativeness.[3] China, a traditionally low-cost manufacturing-oriented economy, saw its high-technology exports as a percentage of total manufacturing exports rise from 10.43% to 25.37% between 1995 and 2014. At just over 25%, China's high technology exports as a percentage of total manufacturing exports now exceed those of the US (18.23%), Japan (16.69%), and the EU (15.42%).

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[3] The use of high-technology trade statistics as an indicator of technological sophistication or domestic innovativeness has, however, limitations. Export statistics do not necessarily reflect the value added to an exported good by the country exporting it (Srholec, 2007:228-299). That is, it is possible, given the increasingly fragmented nature of global production networks, that a country performs only the final assembly of a high-technology product using inputs generated elsewhere (Srholec, 2007). In cases such as this one, export statistics would reflect the value of final product exported, not the value added. As a consequence, "the direct link between the focus of export specialization and local technological capabilities cannot be taken for granted" (Srholec, 2007:228). That said, export statistics do "provide insights into important aspects of trade performance" (Lall, 2000:340) and may be used in conjunction with the other indicators to garner the general overview this research aims to provide.

If investment in R&D activities and innovative output are accepted as a barometers for innovativeness, there is little question that China has evolved from a world laggard in the knowledge economy to one of its leaders. This transformation is by no means complete and there are dimensions within which more advanced economies still have a considerable advantage. Even a cursory comparison of total factor productivity levels in China relative to other advanced economies reveals that China's increasing innovative capacity is not yet manifested in significant productivity gains. That said, all indications point towards a country that is not only becoming more and more integrated in the global knowledge economy, but that is also increasingly shaping it and becoming one of its leaders. In the space of just two decades China has established itself as a major player in the innovation economy, and, more importantly, as a real challenger to the world's most innovative economies.

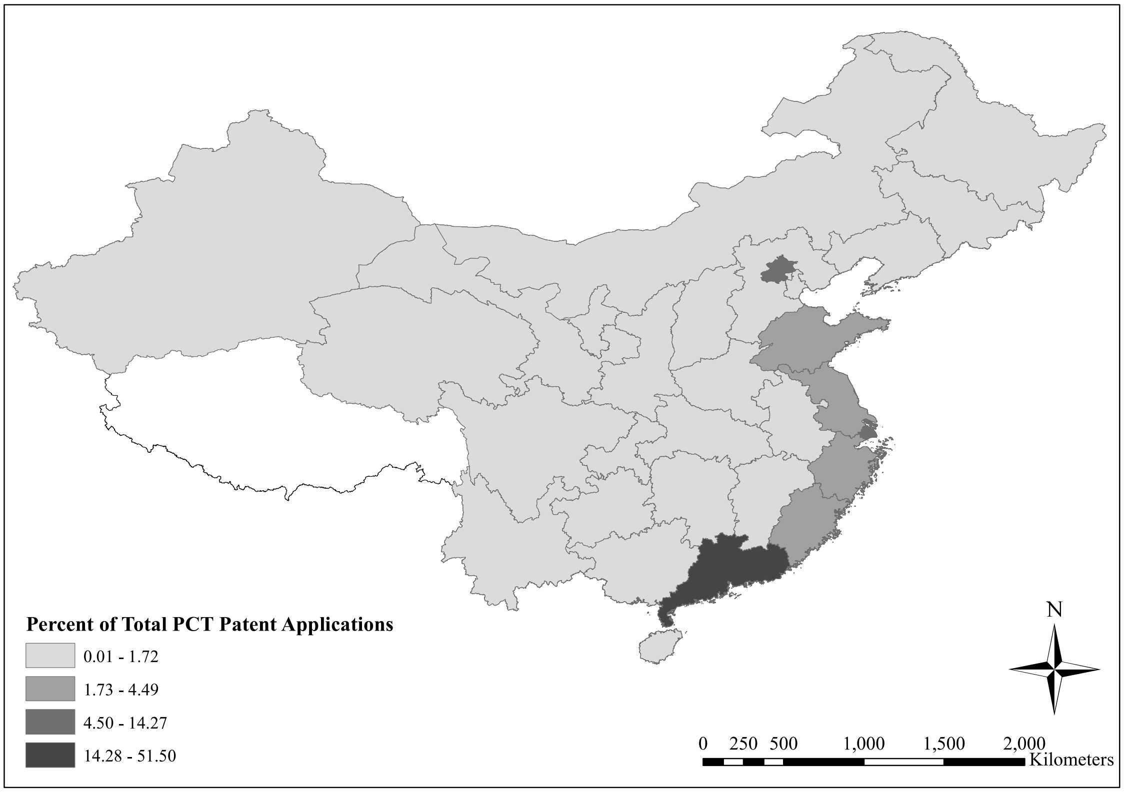
With all of this in mind, our attention must now shift to the development of a more nuanced understanding of innovation in China inclusive of, first, the geography innovative activity in the country and, second, the factors that govern and shape processes of innovation at both the provincial, and in turn, national level.

The territorialisation of innovation in China

Innovative activity the world over has a well-documented propensity to concentrate in core cities and regions (e.g. Ó hUallacháin, 1999; Orlando and Verba, 2005; Bettencourt et al., 2007; Crescenzi et al., 2007; Mitra, 2007; Sedgley and Elmslie, 2011; Guimarães et al., 2013; Lee and Rodríguez-Pose, 2013***;*** Breau et al., 2014). The theoretical explanations for the spatial concentration of innovation are numerous but include, most notably, that the co-location of economic actors in core territories with deeper pools of skilled human capital (Florida, 2003; 2005) and larger stocks of technological infrastructure (Feldman and Florida, 1994) facilitates the generation and exchange of the knowledge that impels innovation (Duranton and Puga, 2001, 2003; Storper and Venables, 2004).

China is one of the extreme examples of the concentration of knowledge generation and innovation in large urban agglomerations. Sun (2003), Wang and Lin (2008), and Crescenzi et al. (2012), among others, have observed that innovative activity in China not only occurs almost exclusively in a handful of regions, but that the tendency towards the spatial concentration in large urban areas of innovative activities has accelerated in recent years.

Figure 8: PCT Patent Applications in China, provincial level, 2010



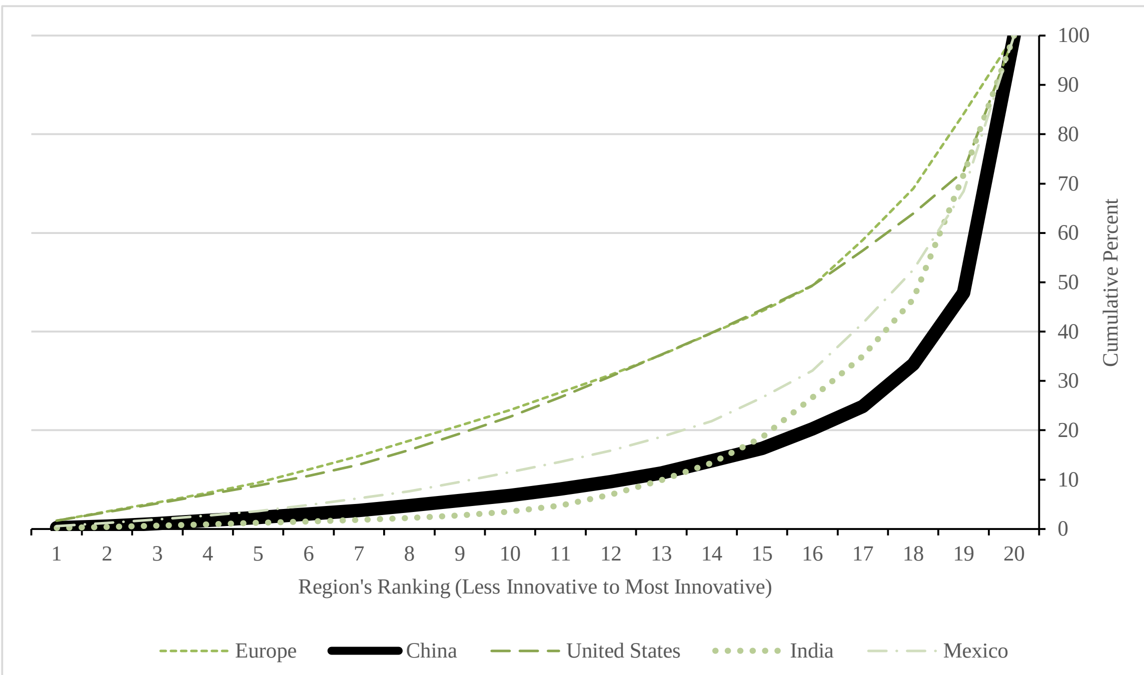
Authors' elaboration, Source: OECD Statistics

Figure 8 illustrates the percentage of total Chinese Patent Corporation Treaty (PCT) patent applications attributable to each province in 2010. The overwhelming majority of innovative activity occurs in China's eastern provinces, along the coast (Figure 8). In particular, the province of Guangdong and the municipalities of Beijing and Shanghai produced the lion's share of innovative output. Guangdong alone accounted for 51.50% of all Chinese patent applications. The second and third most innovative provinces were Beijing and Shanghai, with a share of 14.27% and 8.48% of Chinese PCT patent applications, respectively. Western provinces, by contrast, are decidedly less innovative. Just over 80% of all Chinese PCT patent applications originated in one of five provinces or municipalities – Guangdong, Beijing, Shanghai, Jiangsu, and Zhejiang – each of which is situated along, or proximate to the eastern seaboard.

That these five provinces and municipalities account for such a large share of China's PCT patent application is not surprising given the size of the populations they are home to. More populous regions are indeed expected to produce proportionally greater numbers of patents. The normalisation of patent application statistics using population, however, confirms that these regions are decidedly more innovative than their Western counterparts even in per capita terms. In 2010, Guangdong, Beijing, and Shanghai produced 65.4, 96.4, and 48.8 PCT patent applications per million inhabitants respectively. Most western provinces, by contrast, had negligible levels of per capita patenting in 2010.

Moreover, the spatial concentration of innovative activity in China was more pronounced in 2010 (Figure 8) than at any point in recent history. In both 2001 and 2010, for example, the three most innovative areas of the country were Guangdong, Beijing, and Shanghai. In 2001, these three regions alone produced 60.65% of PCT patent applications in China. Beijing was the leading region, accounting for 26.99% of applications. By 2010 these three regions had significantly reinforced their leadership in knowledge generation, producing 74.26% of all patent applications. However, there were important changes in the urban hierarchy. Guangdong – led by the cities of Guangzhou and Shenzhen – accounted for over 50% of China's PCT patent applications, replacing Beijing as the most innovative province in the process. This increasingly concentration of patenting on the eastern seaboard has seemingly come at the expense of inland provinces. The rest of the country, by contrast, and its central and western provinces in particular, are increasingly playing an ancillary role in knowledge generation. The innovative contributions of once marginally innovative Sichuan, Chongqing, Hubei, and Hunan, as well as the north-eastern province of Liaoning have waned over time.

Figure 9: Spatial Distribution of PCT Patent Applications: Top 20 Most Innovative Regions - China, the United States and the European Union, Mexico and India, 2010



Authors' elaboration, Source: OECD Statistics

While the clustering of innovative activity is by no means a phenomenon unique to China, the degree of spatial concentration it features is greater than in other economies (Figure 9). The difference in levels of spatial concentration of innovative activity between China and both the US and the EU is especially pronounced (Figure 9). Innovative activity in the two areas of the 'triad' is relatively equitably distributed across their 20 most innovation regions. In Europe, no one region accounted for more than 16% of the total PCT patent applications associated with the twenty most innovative regions in 2010. In the United States, only one region (California) produced more than 9%.

Crescenzi et al. (2012:1058) interpret this marked difference in levels of spatial concentration between China – and emerging innovation systems, more generally – and the US and Europe as a reflection of the maturity of the respective innovation systems. That is, more mature innovation systems tend to feature a more territorially equitable distribution of innovative activity.

The degree of spatial concentration of innovative activity in China, however, remains high even when compared to other emerging systems of innovation (Figure 9). In India, for example, the three most innovative states accounted for only 64.95% of the total PCT patent applications attributable India's twenty most innovative regions in 2010. Moreover, only 28.09% of these applications were filed in Maharashtra – India's most innovative state. Similarly, in Mexico, the three most innovative states contributed 58.30% of the total PCT patent applications of the twenty most innovative regions, despite a high population concentration in Mexico City, Guadalajara, and Monterrey. The most innovative area – Mexico City/Federal District – accounted for 31.58% of Mexican patent applications.

A host of inferences relating to the scale, scope, and timing of the evolution of the Chinese innovation system may be drawn from the figures and cursory analysis of the preceding sections. That said, there is, at least in our view, one observation of particular interest that reinforces the need for an exploration of the factors and dynamics governing processes of innovation in China and how they compare with those of both mature and nascent innovation systems: The Chinese innovation system is in a unique position. On the one hand, Chinese investment in innovative activities and its levels of innovative output are commensurate, if not already above, those of some of the world's more innovative economies including, most notably, the EU. On the other hand, however, China remains very much an 'emerging' economy and, perhaps not surprisingly its innovation system shares some spatial similarities with other nascent innovation systems.

The territorial dynamics of innovation: putting China into perspective

Two related, and by no means inconsequential questions emerge from the preceding overview of innovation in China: first, what are the factors that shape processes of innovation in Chinese provinces and have given rise to the considerable spatial concentration of innovative activity? Second, how do those factors compare to those of other mature and emerging innovation systems?

Innovation is understood as a dynamic process that is shaped by a diverse set of structural, socioeconomic and institutional factors, characteristics and conditions (e.g. Edquist and Chaminade, 2006). Recognising this, Crescenzi and Rodríguez-Pose (2012) propose the use of an 'integrated framework' to identify the multitude of influences that condition processes of innovation in different contexts, and to, perhaps more importantly, explore the ways in which they interact – both synergistically and antagonistically – with each other . This framework integrates insights from (i) endogenous growth model; (ii) economic geography approaches; and (iii) regional innovation systems (Crescenzi et al., 2012: 1061) with the aim of cultivating an understanding of the dynamics that underpin regional innovation across heterogeneous territories.

The following section will draw on empirical literature in which this integrated framework has been operationalized and applied (Crescenzi et al., 2007; Crescenzi et al., 2012; Rodríguez-Pose and Villarreal Peralta, 2015) to offer a comparative perspective on the factors that shape the innovativeness of Chinese provinces.[4]

The Chinese innovation system

The Chinese innovation system is, in many respects, quite unique and, in fact, defies expectations founded on more traditional conceptualisations of innovation. Regional R&D expenditure – a presumptive driver of innovation (Griliches, 1979; Audretsch and Feldman, 2004) – for example, is not found to be linked to patenting in Chinese provinces (Crescenzi et al., 2012). Similarly, a series of socioeconomic factors that are anticipated to influence a territory's suitability for knowledge intensive activity, including its supply of skilled human capital, productive use of human resources, and demographic structure, are also not robustly associated with regional innovation in China.

[4] Crescenzi et al. (2007) explored the 'territorial dynamics of innovation' in the US and the EU. Crescenzi et al. (2012) did the same thing for India and China. Rodríguez-Pose and Villarreal Peralta (2015) analysed the drivers of the 'territorial dynamics of innovation' in Mexico.

These notable observations beg the question: what, then, are the factors that influence the processes of innovation in China?

Crescenzi et al. (2012) identify four factors as key drivers of the innovativeness of Chinese provinces: a province's degree of economic specialisation, infrastructure endowment, level of inward migration, and population density. The relevance of these four factors – and the more limited role played by R&D and human capital – to the innovativeness of Chinese provinces suggest that the dynamics of innovation in China are dominated by agglomeration and new economic geography-led processes of innovation (Crescenzi et al., 2012:1075). That is, consistent with the high and increasing degree of concentration of Chinese innovation in the largest coastal metropolitan areas, innovation in China is driven not by investment in knowledge generation or a province's socioeconomic context, but rather by the externalities that arise from the co-location and concentration of economic actors operating in similar sectors – and consequently, the concentration of financial, human, and other resources – in a small handful of well-connected innovative hubs.

This perception is validated by the rather unusual capacity of the largest Chinese metropolitan areas to generate negative innovation spillovers. In contrast to other parts of the world, where territories benefit from the diffusion of the knowledge generated in and by innovation hubs, China's innovative hubs – Guangdong, Beijing, and Shanghai, in particular – are seemingly pulling resources and knowledge away from neighbouring provinces to their own benefit and actually to the detriment of these contiguous regions.

While, in general, it is anticipated that agglomerations may draw resources from other regions as part of a circular process whereby the early concentration of innovative activity in a given region subsequently leads to the outflow of knowledge resources towards surrounding areas, in China centripetal forces massively outweigh centrifugal forces in a manner that is dissimilar to that of the other large developed or emerging economies considered in this analysis.

The marked spatial concentration of innovative activity in China observed in the preceding section is consistent with factors that influence regional innovativeness, and more specifically, with the agglomerative dynamics at play. China's innovative hubs benefit to a greater extent than their counterparts elsewhere in the world from the density of economic activity and the co-location of economic actors that characterise large metropolitan areas as well as from the inflows of knowledge and innovation they are often privy to. They are also more capable of transforming these advantages into patenting activity. The relative dearth of innovation in much of the rest of the country, and in the westernmost provinces in particular, is equally consistent with our understanding of the factors that shape innovation in China. Inland China has, thus far, been largely unable to realise the innovation advantages associated with agglomeration and suffers from an outflow of critical knowledge resources.

Innovation in China versus the developed world

The American innovation system

In the US, regional innovation is governed most prominently by four factors. First, R&D investment is positively and significantly linked to a region's innovative output suggesting that American regions succeed in the transforming basic knowledge into innovation. Second, local socioeconomic conditions influence regional innovative capacity. More specifically, regions with a well-educated, skilled workforce, lower levels of unemployment, and greater numbers of young people are more innovative. Population density and inward migration are also positively and statistically significantly linked with regional innovative capacity. The latter two relationships indicate that the co-location of skilled individuals, together with the interactions, collaboration, and exchange of knowledge facilitate regional innovativeness (Crescenzi et al., 2007).

The European innovation system

Regional innovation in the EU is influenced most significantly by three broad elements: a) a favourable socioeconomic context, and, in particular, the quality of the pool of human capital; b) exposure to knowledge spillovers; and c) the agglomeration of economic activity, proxied by the percentage of national GDP attributable to a given region. Agglomeration externalities are seemingly an important component of the innovation system as well.

Comparing the innovation systems of China, the US, and the EU

The respective innovation systems of the US and the EU serve as useful foils for the Chinese innovation system in an effort to develop an understanding of how the factors shaping innovation in China differ from those of a more mature innovation system. While the three systems do share some similarities, the differences are far more numerous.

The American and European innovation systems share one notable similarity: local socio-economic conditions play a fundamental role in explaining differential innovative performance. That is, in the mature innovation systems of the European Union and the United States, a region's socioeconomic context would seem powerful determinant of its innovative capacity. This is not the case in China –the empirical analysis upon which this paper draws provides no evidence to suggest that socioeconomic conditions are significantly linked to territorial innovativeness in the Chinese context.

Another crucial difference between China's innovation system and that of the US relates the relationship between R&D investment and the generation of innovation. As addressed, provincial R&D expenditure has not emerged as a key driver of regional innovation in China. In the US, however, the level of R&D investment in a given region shapes, to a large extent, its innovative capacity. Similarly, when comparing the European innovation system to that of China, there is a noticeable difference in terms of the role of R&D and knowledge spillovers. In the EU, a region's exposure to knowledge spillovers positively influences and is fundamental to the innovativeness of that region, especially in the core areas of Europe (Rodríguez-Pose and Crescenzi, 2008). There is no evidence of such a dynamic in the Chinese system except in the few innovative agglomerations that, as addressed, draw on the knowledge and innovative activities of neighbouring regions. Beyond the innovative hubs, however, there is nothing to suggest that R&D spillovers have a significant effect on provincial innovation in China.

In spite of these prominent differences, there is at least one broad similarity between the three innovation systems. In China, the US, and the EU, regional innovation benefits from externalities arising from agglomeration *of one form or another*, although the role of agglomeration differs considerably between the three economies. In China, agglomeration-related externalities are the preeminent influences on regional innovative capacity. In the US and the EU, externalities arising from the co-location of skilled individuals and economic activity, respectively, are a non-negligible piece of the innovation puzzle. They are not, however and in contrast to China, the only or even the main relevant factor behind innovation.

The contrasting geographies of innovation in China and the US and EU are a reflection of the differences in the factors underpinning processes of innovation in the three contexts, and of the importance of agglomeration externalities in particular. That is, the concentration of the majority innovative activity in three Chinese provinces and municipalities is consistent with an innovative process that relies on co-location and within-region induced externalities. Similarly, the *more* equitable – though still unequal – spatial distribution of innovative activity in both the EU and the US is consistent with the less prominent role played by externalities and, conversely, the greater importance of other, especially local, factors including, for example, socioeconomic conditions.

Innovation in China versus other emerging countries

The Chinese innovation system also differs considerably from those of many emerging countries. In this sub-section we compare the geography of China's innovation system with the territorial systems of innovation of two large emerging countries: India and Mexico.

The Indian innovation system

The Indian innovation system, as Crescenzi et al. (2012) suggest, conforms to a more 'traditional' innovation story. Four independent factors appear as the fundamental drivers of regional innovation in India. First, regional R&D investment is positively linked with greater innovative output, as are knowledge spillovers. Favourable local social conditions inclusive of the stock of skilled human capital and the productive use of human resources are also associated with greater regional innovative capacity. Finally, a positive relationship exists between levels of inward migration and innovation.

The Mexican innovation system

The Mexican innovation system contains elements that are more similar to those found in India or the EU than in China.. Regional R&D investment and local socioeconomic conditions – levels of educational attainment, in particular – combine at the local level in order to increase the innovative output of Mexican states. Spillovers also fuel regional innovativeness (Rodríguez-Pose and Villarreal Peralta, 2015). As was the case in both the EU and India, R&D spillovers are linked with greater regional innovation. Unique to the case of Mexico among the countries considered is the evidence that suggests that social spillovers matter for innovation. That is, a region's innovative capacity is positively influenced by more favourable socioeconomic conditions in neighbouring regions. In Mexico, however, innovation is still very much hampered by an insufficient commitment to the upgrading of the innovation system (Rodríguez-Pose and Villarreal Peralta, 2015). That is, greater resources need to be allocated to strategic efforts to promote innovation if "radical change to the Mexican economic trajectory" is to be achieved (Rodríguez-Pose and Villarreal Peralta, 2015:191).

Comparing the innovation systems of China, Mexico, and India

The comparison between the innovation systems of India, Mexico and China is particularly relevant given their emerging country status and the relative youth of their respective innovation systems. Yet, despite these common traits, prominent differences exist across all three systems, and especially between that of China, on the one hand, and those of India and Mexico, on the other.

The similarities between the Indian and Chinese innovation systems are few and far between. In fact, India's innovation system shares more similarities with those of the US and Europe than it does with that of China. Processes of innovation in India are very much shaped by the traditional drivers of innovation, none of which is significantly linked to innovation in the Chinese context. Moreover, the forces of agglomeration that are instrumental for innovation in Chinese provinces do not stand out as shapers of innovation across Indian states, with the lone exception of inward migration. Crescenzi et al. (2012:1076) report that the interaction between R&D investment and population density facilitates innovation in urban India. This is interpreted as indicative of the existence of returns to the territorial concentration of R&D efforts, suggesting that the innovativeness of Indian regions is explained – to a much more limited extent than in the case of China – by the existence of agglomeration externalities arising from the concentration of knowledge generation efforts.

Finally, the Mexican innovation system and the Chinese innovation system bear almost no resemblance to one another. None of the factors that shape innovation in Mexican provinces are found to be significantly linked to the innovative capacity of Chinese provinces.

Putting it all together

The aim of the preceding section was not to provide an exhaustive analysis of each of the individual factors that influence processes of innovation in China, the US, the

EU, India, and Mexico, respectively. Rather, we sought to, first, identify the factors that seem to be most significantly linked to regional innovativeness in each of the five economies considered, and second and more importantly, highlight the key similarities and differences between them. Two related conclusions emerge from such an exercise.

First, no two innovation systems are identical, implying that there is no single model of a geography of innovation. Moreover, there also is no specific territorial model of innovation for developed countries, on the one hand, and for emerging countries, on the other. A number of traits are, however, shared across *some* of the innovation systems considered. In the EU, the US, India, and Mexico R&D investment is, more often than not, a fundamental determinant of knowledge generation. The returns to R&D are also enhanced when the local socioeconomic conditions are favourable, implying that a better endowment of human capital, lower levels of unemployment, and sectoral structures are factors adept to knowledge generation and diffusion. In the EU, India, and Mexico knowledge spillovers also play a non-negligible role in facilitating patenting. In these areas the most innovative regions are those that offer suitable socio-economic conditions, but also those that are capable of absorbing, assimilating, and capitalising upon R&D and knowledge spillovers (Crescenzi et al., 2007:703).

China, however, stands out from the rest, with a distinctly unique geography of innovation. The Chinese innovation system is founded, most immediately, on the agglomeration of economic activity and the externalities it produces. In China agglomeration externalities both facilitate innovation itself as well as the absorption of innovative potential from other regions. R&D investment, human capital endowments, and knowledge spillovers are far less prominent as factors driving innovation. Indeed, the Chinese innovation hubs suck resources from neighbouring regions, contributing to a much greater concentration of innovative activity than that witnessed in any of the other cases considered. Hence, knowledge spillovers in China happen within the boundaries of regions – and, more often than not, in highly dense and agglomerated metropoli – rather than across regions.

Overall, regional innovation in China is most directly linked to externalities arising from the co-location of economic actors than to the more ‘traditional’ factors behind innovation: R&D, human capital, and knowledge spillovers. This has given rise to a unique geography of innovation, characterised by a huge concentration of innovative activity in the largest metropolitan areas of the country. While these agglomeration externalities are at play in the innovation systems of other countries, they tend to be much more synergistically connected than in China with the more ‘traditional’ drivers of innovation.

The role of the Chinese institutional context in shaping the growth and evolution of China’s innovation system also warrants brief mention here. Crescenzi et al. (2012:1075) highlight, for example, that “[the concentration of innovative activity in Guangdong] is in many ways the result of a national strategy designed to turn China into the workshop of the world”. Similarly, the establishment of Special Economic Zones in a selection of coastal provinces is, at least in part, responsible for their relative innovativeness as are policies that regulate the inter-territorial movement of both capital and labour (p. 1076). Although a detailed investigation of the Chinese institutional context is beyond the scope of this taxonomic paper, it must be made explicit that the unique institutional context has been a non-negligible influence on the development of a geographically unique innovation system, the importance of which cannot be overlooked.

It would therefore seem that China is evolving from an innovation laggard into an innovation leader by building its own, very distinct territorial dynamics of innovation. China is forging an innovation path that is markedly different to the ones trod by not only more mature innovation systems, but emerging ones as well. These territorial dynamics of innovation are not without consequence. They have profound implications for regional economic growth and dynamism and, relatedly, are contributing to the proliferation of spatial inequality.

The need for place-based innovation policies

The inferences drawn in the preceding section point in the direction of two policy considerations. First, and most generally, it would seem that the development of multidimensional, territorial specific innovation policies (e.g. Tödtling and Trippl, 2005; Crescenzi and Rodríguez-Pose, 2012) is becoming increasingly necessary. The once prevailing view that innovation is a linear process in which greater investment in knowledge generation is anticipated to yield proportional increases in innovation (e.g. Maclaurin, 1953; Griliches, 1979) has been replaced by conceptualisations of the innovative process as non-linear, evolutionary and, most importantly, governed by a host of inevitably territorially-specific socioeconomic, institutional, and political factors and influences (Edquist and Chaminade, 2006). Moreover, as the preceding section illustrates, the relative importance of each factor or influence, and, critically, the way in which they interact with one another varies enormously across territories. Consequently, the application of one-size-fits-all innovation policies grounded in unidimensional, linear conceptualisations of innovation, or, similarly, the replication of 'best-practices' from one part of the world in another will likely be inadequate. This is especially true for China, where the territorial polarisation of innovative activity has become more conspicuous than in other parts of the world. If they are to avoid further polarisation and the economic, social, and political risks associated to it, Chinese policy makers must acknowledge the heterogeneity of innovation processes and adopt policies that reflect the vastly different innovation realities of innovation hubs, such as Guangzhou, Shenzhen, or Beijing, and innovation 'deserts', such as Qinghai and Guizhou. Innovation policies – even more in China than elsewhere – need to identify and understand the contextually contingent drivers of regional knowledge generation and assimilation, so that resources may be allocated efficiently and in response to the factors and dynamics that actually shape processes of innovation – be they economic, social, institutional, or otherwise – in every territory, rather than to the further stimulation of R&D activity in the potentially vain hope that knowledge and innovation are going to spill over from the knowledge 'hubs' and reach all corners of the country.

The second policy implication derives from the observation that processes of innovation in China are governed by a set of factors distinctly different to the four other countries considered in this paper. *It is therefore vitally importantly that innovation policies and strategies pursued in China will need to reflect those differences*. Innovation policies adopted in China need to be based on a thorough diagnosis of both the dynamics underpinning processes of innovation and, in time, an examination of which approaches have worked and which ones have not. The Chinese innovation policies must respond to the empirically verifiable importance of agglomeration and the externalities it gives rise to as drivers of innovation. Policies must also, however, be acutely aware of the potential medium- and long-term problems of an excessive geographical agglomeration of knowledge generation. The territorial concentration of innovativeness and innovative capacity has frequently been equated with the territorial concentration of the potential for economic growth and development (Howells, 2005). Hence, although until now the concentration of innovation in Guangdong province, Shanghai, and Beijing may have contributed to enhance the overall national innovative capacity, further concentration may become counter-productive for both innovation and economic growth. On top of the negative externalities that excessive agglomeration may generate in these large metropoli, the concentration of resources and outputs in a very limited number of places in China is raising urgent concerns about the accentuation of within-country territorial inequity, illegal migration, social and emerging political problems, and, relatedly, about the welfare of individuals living beyond the more innovative core provinces.

There is therefore a need for strategic approaches that seek, without undermining the overall efficiency of the innovation effort, to contribute to a more balanced geographical distribution of the innovation capacity and the economic growth it impels throughout the remainder of the country, perhaps promoting the development of the central regions in a first stage before targeting the most peripheral areas of the country. Promoting innovation outside of established innovative regions in the developed and developing world alike is, however, fraught with difficulties. Achieving this lofty ambition in China may be especially challenging given the role that agglomeration externalities play in processes of regional innovation. It may not be easy to achieve the necessary levels of density of skilled individuals, innovative firms, and other economic actors outside of the established innovative hubs. Policy-makers will therefore have to develop a nuanced understanding of the unique dynamics of innovation in these provinces and attempt to devise policies that do not just rely on agglomeration, but rather respond to other factors that could potentially catalyse innovation.

In sum, policy-makers will be forced reconcile and integrate innovation policies that support and foster the established innovative hubs with those which seek to impel innovation and innovation-driven economic growth across the remainder of the country. The adoption of such a holistic approach to innovation will be essential should China wish to develop a sustainable innovation model that will ultimately nurture future evolutionary trajectories and better and more sustainable economic outcomes.

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