Econ Polit (2018) 35:71–106
https://doi.org/10.1007/s40888-017-0088-9

The diffusion and embeddedness of innovative activities in China

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Received: 4 June 2017 / Accepted: 18 November 2017 / Published online: 27 November 2017

Abstract China's unprecedented growth largely results from industrial development having critically sustained the country's economic transition after 1978. As common to the developmental context, catching-up capabilities have been both absorbed from external sources and generated by indigenous activities. These also represent exogenous and endogenous seeds of innovative activities respectively. The relative emphasis on the two has evolved over progressive industrialization–transition stages in China, leading the country to grow a global manufacturing hub. The volume and quality of innovative activities has however resulted unevenly distributed at a local level. Literature considers embeddedness, in particular, as one of the key features in the development of the local innovative environment. This paper investigates if the mixes of seeds may have delayed the innovative activities to gain embeddedness along their diffusion in the Chinese prefectural cities. In a great deal of stylization and methodological design, innovative activities are here approximated by the applications to the European Patent Office from China collected in the OECD REGPAT database as originally rearranged by the applicant's and inventor's prefectural locations. These locations are taken to build three indicators to be combined in a clustering procedure set to measure separate levels of embeddedness. The results suggest a growing diffusion and embeddedness of the innovative activities in the Chinese prefectural cities since the early-2000s, despite they remain highly concentrated in some regions, that is, mainly those having historically hosted the Special Economic Zones where more exogenous seeds appear to have actually delayed the innovative activities to gain embeddedness.

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Keywords China · Embeddedness · Innovation · Patent · Prefectural city

JEL Classification O33 · O38 · R12

1 Introduction

China's economy has experienced unprecedented growth in the post-Mao era. According to the World Bank's World Development Indicators, country's income per capita has grown + 8.8% a year on average between 1978 and 2008, that is, impressively more than in other emerging economies like India (+ 3.6%) or Brazil (+ 1.2%). Such a sustained growth has intertwined with the transition towards market economy, which is at the very basis of the country's developmental strategy launched in the late-1970s and has benefitted from a key governmental focus on upgrading country's industrial capabilities. The attainments are evident in the Chinese exportations of manufactured goods having reached, according to the UNCTAD statistics, 12.7% of the world total value in 2008 and 18.6% in 2015.

China has grown a global manufacturing hub in many industries. A paramount example is the industry of electronic devices and components, in which the country's Revealed Comparative Advantage (RCA) can be estimated around 2.5 since 2008 onwards, based on the UNCTAD statistics, meanwhile companies like Huawei, Lenovo and ZTE have gained a global leadership. The diffusion of domestic innovative activities is a substantial driver of this process, whose achievements build on a mix of imported and indigenous capabilities (Fu et al. 2016). The relative emphasis on the pair of these sources has strategically evolved over separate stages along the country's industrialization–transition path: preparing for the market economy until the early-1990s, opening to the international economy before the World Trade Organization (WTO) membership in 2001, and then the socialist market economy (Frattini and Prodi 2013a; Naughton 2007).

Imported and indigenous capabilities can be respectively considered as exogenous and endogenous "seeds" of innovative activities. Each stage-specific mix of these seeds has been crucial for the success of the Chinese way to economic restructuring and catching up with industrialization (Fu et al. 2016; Prodi et al. 2017). Nonetheless, the nature of the seeds should be expected a diverse effect on innovative activities, especially on them to embed locally. Literature largely considers embeddedness as one essential property of well-structured local innovative environments (Boschma 2005; Cooke 2005; Maskell and Malmberg 1999; Torre and Rallet 2005). This paper aims to explore how the mix of seeds along China's development may have affected this property in the long-term.

More precisely, the research question is whether, despite of an exceptional push on economic growth, more exogenous seeds can have somehow delayed innovative activities to gain embeddedness locally. On one hand, literature has reported the surge and diffusion of the innovative activities in China. On the other, it has focused on place-specific features of the local innovative environments (see Fan 2014 for a survey). This paper aims to contribute the literature giving original insights into between these two research lines. It designs an empirical strategy to measure and map countrywide the embeddedness of innovative activities at a prefectural level in China, so that the linkage with the nature of seeds can be discussed.

In doing this, the paper is expected to serve development economists and practitioners, focusing on the primary and secondary effects of the exogenous seeding of innovative activities to promote industrial upgrading, that is, diffusion but delayed embedding. It is well-known in literature that attracting foreign investments to import "packaged" technologies may entail a sort of "truncated" technology transfer, i.e., the upgrading of indigenous capabilities "up to a certain level, but not beyond" (Lall 1992, p. 179). Efficiency in technology transfer depends indeed more on the capabilities to absorb and link with than to replicate and update the imported technologies (Lall 1992). Innovative activities persisting to be relevantly fostered by exogenous seeds even in regions where China's catching up has been most successful and native global innovators reside today, it would be an important piece of evidence of a possible long-term effect produced by a very popular strategy to promote the diffusion of innovative activities in the developing countries. The remainder of the paper is outlined as follows.

Section 2 briefly frames the Chinese developmental strategy after 1978, focusing on the industrialization–transition synchronism and the contextual diffusion of innovative activities along this path. Special attention is given to the policy devices implemented to seed this process, and uneven embeddedness is discussed as constitutive of the diffusion of innovative activities in the country.

Section 3 moves to design an empirical strategy to measure embeddedness. It starts from the option of using patent applications as a proxy of innovative activities (Keller 2004) and from considering the investigation at a prefectural level as the most appropriate for the purpose of this paper. Patent counts by inventors' and applicants' location between 1981 and 2009 are combined together into three indicators entering a clustering procedure to rank innovative activities into separate level of embeddedness.

This approach is very demanding detailed data. Such an extensive information on patent applications from China is not commonly available however. The data set used in this paper is an authors' original rearrangement of the patent filings at the European Patent Office (EPO) collected in the OECD REGPAT database (as released in January 2014). The results are presented in Sect. 4. First, different groups of prefectural cities are mapped countrywide by level of embeddedness. Second, the linkage between these levels and the local seeds of innovative activities is qualitatively discussed in a sample of prefectural cities to give insights into the answer to the research question.

Finally, Sect. 5 makes room for conclusive remarks and derives policy implications that are relevant to China and, more in general, to the developing countries whose industrial development has meaningfully relied on exogenous seeding or it continues doing so. According to the UNCTAD statistics, the stock of inward Foreign Direct Investments (FDI) exceeded the 50% of Gross Domestic Product (GDP) in 20 countries in 2005 and the 100% in eight of them. The number of these countries then increased up to 49 and 17 respectively in 2015.

2 Seeds of industrialization and diffusion of the innovative activities in China

China is acknowledged as “world’s factory” today (Ma et al. 2009). This is the result of unprecedented economic growth and very fast catching up with industrialization started in the late-1970s. The pair of them have roots in the pathway to country’s development designed on new elements having entered the political debate after Mao’s death: the transition towards market economy and the integration into the global markets (Naughton 2007). On one hand, China was required deep transformations along this path. On the other, these transformations have been kept aligned with one another by a comprehensive governmental strategy aimed to make the pathway as the most successful as possible (Frattini and Prodi 2013a).

The accumulation of industrial capabilities is at the core of that strategy (Brandt et al. 2008; Naughton 2007). Historically, industrialization is the engine of economic catching up (Rodrik 2016). There is indeed a positive correlation between the growth of GDP and the growth of the manufacturing sector (Kaldor 1967). Furthermore, latecomers are expected to gain more than industrialized countries from the substitution of obsolescent capital endowments (Abramovitz 1986). As well-known in literature, there are two substantial ways to this accumulation: it can be generated indigenously taking a quite long time, or it can be more quickly imported from abroad (Lall 1992). China’s successful experience relies on having purposefully mixed the two of them (Fu et al. 2016).

A main issue in importing capabilities is how they can be properly absorbed (Cohen and Levinthal 1989), that is, the extent they spillover into new endogenous sources of growth. In turn, absorption and endogenization rest on strong enough indigenous capabilities, motivating to timely modulate the emphasis on the one or the other way to industrial upgrading. These ways have actually evolved into stage-specific mixes in the post-Mao China, to whose regard literature identifies various turning points dependent on the specific focus of the periods, such as on reforms, industrial capabilities and economic development in Naughton (2007), or on country’s innovation policy in OECD (2008) and Fu et al. (2016). Here, it sounds particularly appealing to follow Naughton (2007) in looking at the broader picture and then setting three main stages after 1978.

As summarized in Frattini and Prodi (2013a), the first stage originated from the political debate on a new pathway to country’s development along with the transition from planned to market economy. The opening steps were to dismantle some of the governmental control over the economy and to introduce fundamental market players of course. Other important initiatives included to define a dual track regime allowing the State-Owned Enterprises (SOE) partially and the Town- and Village-owned Enterprises (TVE) completely to run their businesses outside the plans. Private Small and Medium Enterprises (SME) and foreign companies were also allowed to operate in China, albeit the lasts initially limited to joint ventures with domestic companies.

So far, 5-year plans nonetheless continued being the chief governmental device to frame the wide set of policy initiatives in the country, including those related to industries and technology. Investment opportunities, in particular, were further detailed in periodically updated guidance catalogues. Foreign investments were allowed, encouraged, restricted or prohibited accordingly, depending on the sector and the related governmental priorities. For instance, many activities in the service sector left the prohibited for the restricted catalogue in 2002 to comply with the entry in the WTO in 2001 (Davies 2013). Later, industries like environmental protection, energy resources, and clean automotive have been included into the list of the encouraged sectors in 2011 as key to supporting country's environmental policy (Ng 2013).

A number of Special Economic Zones (SEZ) were established as preferential doors to international trade and foreign investment inflows. These zones were strategical to start realizing the so-called "Open Door Policy", that is, favoring new connections between the domestic and foreign business as well as grounding the premises of the country's external expansion (Rawski 1994; Wu 2008). The SEZ in the strict sense are those established in Shenzhen, Zhuhai, Shantou, Xiamen in the early-1980s, and later also in Hainan, Shanghai and Tianjin (Zeng 2010). They are geographically delimited areas "with a single management or administration and a separate customs area (often duty free), where streamlined business procedures are applied and where firms physically located within the zone are eligible for certain benefits" (World Bank 2010, p. 304). It is in these very locations where, at the beginning, the Multinational Enterprises (MNE) have mostly concentrated their investments in China, peaking at 60% over the total inflow of FDI to the country in 1981 (Wong 1987).

China was therefore no longer hermetically sealed to the market. Although the transition was largely uncompleted (Rawski 1994) and market relations still biased by governmental interventions (Brandt et al. 2013; Zhang and Tan 2007), country's transformation was quickly on the go. The SEZ became places where to experiment local policies (Heilmann 2008), even pushing state restructuring (Prodi et al. 2017). Meanwhile, foreign technologies started being imported together with the FDI, so that the SEZ crucially "seeded" the early country's industrial upgrading (Fu 2008).

Despite the sources of upgrading feature intrinsic exogeneity in this context, the stream of improvements and the consequent economic development they foster does not remain isolated from other more endogenous concurrent dynamics. If successful, the ongoing exogenously and endogenously driven processes should be rather expected to interlace with one another in pushing structural change. Reforms in China are a paramount example of such an interlacement and the potential size of its success. First, the transition was essential to create opportunities to improve the country's economic performance based on market and international trade. Second, state downscaling was critical to start developing indigenous institutional capabilities to realize those opportunities (Prodi et al. 2017). In this sense, as noted in North (1990), economic performance critically depends on institutions and institutional change, whose nature is by definition endogenous regardless of the sources of upgrading.

Reforms were nonetheless cautious during this first stage following a sort of "no loser" approach (Lau et al. 2000). Nonetheless, that approach grew inconsistent with the concerns emerged by the late-1980s. The FDI were pressuring industries into developing new upstream and downstream linkages (Sun 2012), as they had introduced increasing competition (Brandt and Thun 2010) and new technological issues (Girma et al. 2008). The overall country's strategy therefore entered a second stage and, combined with indigenous accumulation of physical and human capital, the MNE's local businesses helped some of the domestic companies to access international value chains, as well as innovative activities to diffuse (Chen 2007).

Innovative activities have dramatically increased in China since the mid-1990s (Fig. 1). As the same as in other contexts, their diffusion has been prepared and supported by complementary devices to those aimed to boost economic growth, such as industrial, technological and science parks, i.e., agglomerations of physical infrastructures in the higher-technology domains, which also pair with additional functional components, such as services and financial providers, business incubators and accelerators, and measures to attract high-skilled professionals (World Bank 2010).

An extensive intervention on the country's Science and Technology (S&T) system was accordingly necessary. The fundamental state infrastructure was built under the sixth 5-year plan (1981–1985) with the National Key Technologies R&D Program, the State Key Laboratory Program, and the University reform. Later on, under the seventh and eighth 5-year plans (1986–1995), the Spark, the Torch and the Technology Spreading Program focused instead more on parks and incubators (Huang et al. 2004). Public laboratories started being contextually transformed into business entities, promoting industrial collaborations and competitive funding (OECD 2008).

Importantly, these S&T components represented additional seeds of upgraded country's industrial capabilities favoring new indigenous business activities to spin

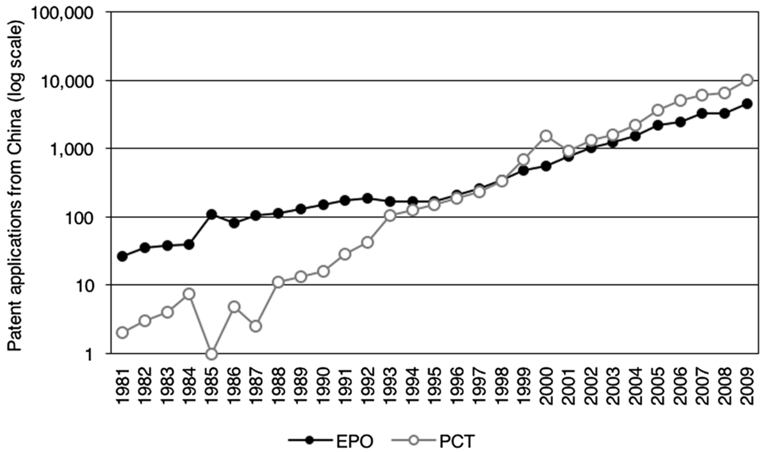

Fig. 1 Number of patent applications from China to the EPO and under the PCT: applicants, logarithmic scale, 1981–2009. Source: authors' arrangement from the OECD Statistics

off or cluster around (Hu 2007). As an example, Lenovo computer, a famous Chinese MNE that is leader today in the personal computer industry, was established as a spin-off company of the China Academy of Science (CAS) in 1984 (Tzeng 2011). As such, this generation of seeds can be considered to have a more endogenous nature, so that they went complementarily adding to the former in contributing to the later upsurge of innovative activities in the country. Meanwhile, 5-year planning was rescaled to a substantial addressing role, earlier indigenous business activities were pushed to restructure and reforms were extended to the SOE becoming now bigger, more capital- and knowledge-intensive, more productive and capable to profit (Gabriele 2010).

The consequent accomplishments get the country ready for a new step into the market economy giving way to a third stage opened by the China's WTO membership in 2001. The incentives to attract foreign companies were reduced, and shifted to empowering more indigenous sources of development. Some industries were considered so strategic as to promote the growth of national champions (Hemphill and White 2013) and to acquire relevant assets in foreign countries (Deng 2009). This further pressured into the normalization of formal rules, such as to amend the law protecting Intellectual Property Rights (IPR) first enacted in 1985 (Hu and Jefferson 2009).

China's developmental achievements hence arrived at the doorway of the knowledge-based economy. In these years, the "catching-up" argument was definitely replaced by the excellence of the S&T system in the national policy agenda (Sun and Liu 2010). The country's developmental targets concurrently shifted from the production of goods to the production of knowledge (Hu and Mathews 2008). By the early 2010s, two of the five world leading companies in the quite recent-born smartphone industry will have been Chinese, i.e., Huawei and ZTE (Zhang and Zhou 2015). These very two companies will have also reached to be listed soon among the top 20 PCT applicants (WIPO 2013).

This is just one example of the wider industrial upgrading fulfilled in China, although its sectoral characterization is evident and congruent with the faster catching-up opportunities the middle-income countries can find in shorter cycle-time technological domains (Lee 2013). There are several other industries, in fact, in which China's industrial upgrading still critically relies on the collaboration with and technology transfer from foreign companies in joint ventures, such as the automotive sector (Nam 2011).

China's economic growth is largely dependent on the gains in innovation capacity (Fu et al. 2011). Indigenous as much as imported capabilities have played a crucial role in making the country to climb up the ladder of industrialization so fast. Nonetheless, tumultuous growth has produced sizeable structural disparities across regions (Frattini et al. 2017), which are evident in the diffusion of the innovative activities throughout the country. If the number of cities hosting innovators has significantly increased over time, innovative activities remain highly concentrated in a few of them regardless (Fig. 2).

As a matter of facts, country's economic transformation has taken root in the Coastal region first, especially nearby the SEZ. As sources of import technologies and knowledge, international trade and foreign investments in these areas helped

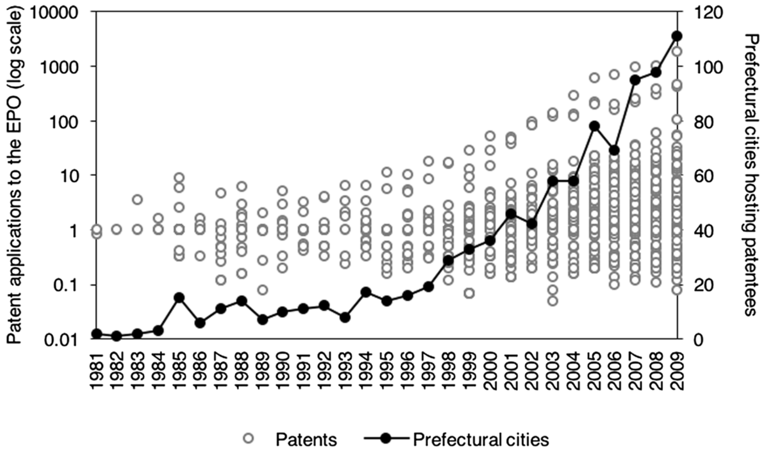

Fig. 2 Number of patent applications to the EPO from China by prefectural city (logarithmic scale, left axis) and number of prefectural cities hosting EPO's patentees (right axis): inventors, 1981–2009. Source: authors' arrangement for the OECD REGPAT database, January 2014

dramatically boost economic growth, having even exceeded a 50% yearly rate in Shenzhen between 1981 and 1984 (Wong 1987). They also pushed the catching up with industrialization largely in advance of other Chinese regions so that it is right in the SEZ and in a few other "supercenters" where innovative activities are still very concentrated (Crescenzi et al. 2012).

The clustering of more indigenous activities started being emphasized some years later, also encouraged by a shift from a "defying" to a "following" comparative-advantage approach (Lin and Wang 2012), as well as by protection loosening in some industries (He et al. 2008). These agglomerations are mainly located in the Coastal region too, from Beijing in the Northeast to Hainan in the Southeast, the largest in the provinces of Jiangsu, Shanghai, Zhejiang, Fujian and Guangdong and very close to the SEZ in some cases (Frattini and Prodi 2013b). Economic growth, industrial upgrading and the diffusion of innovative activities around more endogenous seeds can have largely benefitted indeed from the proximity to complementary more exogenous ones.

Focusing on innovative activities, a common way they can be localized is to look at the regions patents' inventors are located. Inventors are a quite reliable proxy of the human capital embodying the capabilities to innovate. They do not help localize however the effort in funding innovative activities and the opportunities to appropriate the returns on them, which are as much essential elements of the innovative process. Conceptually, these elements can be better captured by the location of patents' applicants. Combined together, counting patents by both the location of inventors and applicants can then offer a comprehensive characterization of the local diffusion of innovative activities.

The distance between the values of the two counts is often very large in those regions where innovative activities are poorer. In these regions, applicants tend to be less densely located, given that the innovative processes are usually less structured.

In other words, innovative activities started being performed around seeds that originate from elsewhere: this is right the substance of exogenous seeding. Nonetheless, Fig. 3a, b show that the distance between the two counts is quite evident also in those locations innovative activities are mostly concentrated. In particular, the prominence of foreign applicants it is still sizeable in 2009 despite of having decreased over time.

When innovative activities significantly rely on non-indigenous applicants, they can be supposed little embedded locally. Literature reckons embeddedness to be one of the crucial properties of well-structured local innovative environments. Regional Innovation Systems (RIS), for instance, are attributed indigenous capabilities to produce, as well as to sponsor, govern, and make commercial use of innovations (Cooke 2001; Cooke et al. 1997, 1998). More in general, embedded innovative

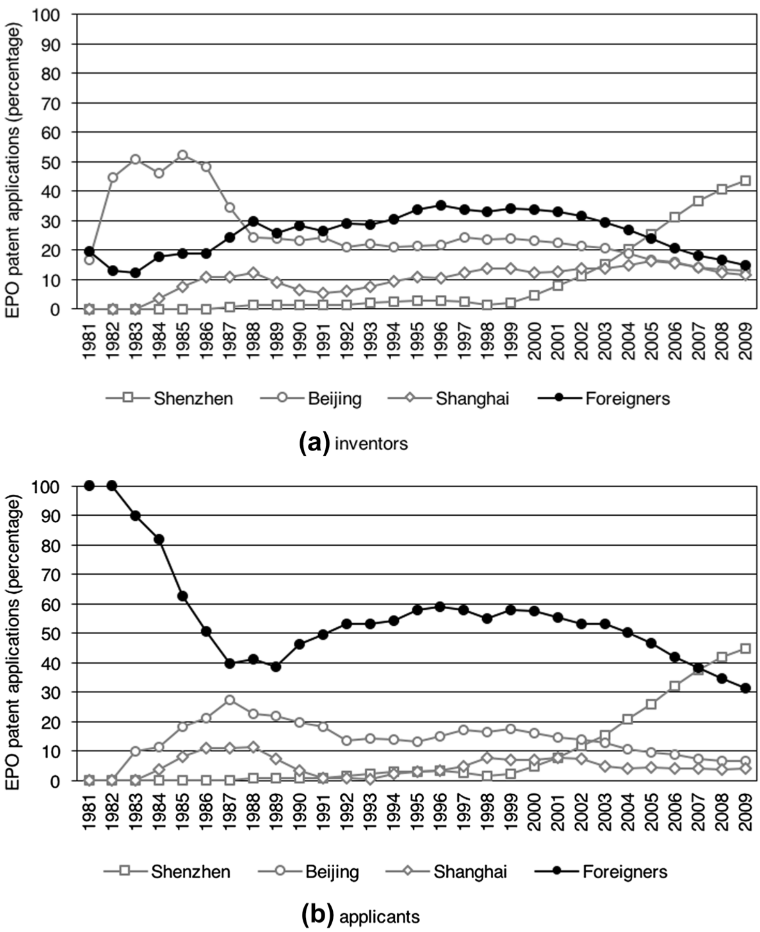

Fig. 3 Patent applications to the EPO by patentees' location: main cities and foreigners, percentage, 5-year average, 1981–2009. Source: authors' arrangement from the OECD REGPAT database, January 2014

processes are expected localized learning capable of “distinctive cognitive repertories” (Malmberg and Maskell 2006, p. 1) that can contribute to restructure both the economic and institutional pillars of industrial upgrading (Maskell and Malmberg 1999). Local knowledge and innovative capabilities can take actually advantage from being more outward-oriented than outward-dependent (Bathelt et al. 2004). In this sense, embeddedness is no less than essential to give local networks and institutions strength enough to anchor economically-relevant processes, such as innovative activities, to very local dynamics (Granovetter 1985, 2005).

This paper focuses on how endogenous and exogenous seeds affect the process the innovative activities embed through. More exogenous seeds have actually boosted the diffusion of innovative activities in China, but they can be supposed to have delayed these activities to gain embeddedness. In particular, successful exogenous seeds, as proved by fast local economic growth and catching up with industrialization, are expected to persist being strongly concentrated where they have first agglomerated. They may therefore still result a prominent component of the local innovative environment decades after they started agglomerating. Actually, the number of foreign patent applications to the State Intellectual Property Office of the People’s Republic of China (SIPO) continued outweighing those domestic until the early 2010s (Zhang and Zhou 2015). It is no doubt indeed that the truncation of technology transfer highlighted in Lall (1992) is two-way efficient. On one hand, it better protects the exogenous innovative effort from easy indigenous imitation. On the other, it contains the indigenous absorptive capacity required to fulfil the local portions of the exogenously driven innovative processes. As a result, the pace the additional portions of these processes are further absorbed should be expected to slow down while the exogenous seeds to last being central nodes. The main challenge in investigating this hypothesis is to set a proper empirical strategy to measure embeddedness.

3 Measuring the embeddedness of innovative activities

Innovative activities are complex intangible phenomena that are impossible of accurate measurement. Some proxy is therefore necessary. An option is patent statistics, that is, a measure of the output of the innovative activities (Dernis and Guellec 2001; Keller 2004). As usual in every approximation, there are shortcomings however. First, it is difficult to compare the economic relevance of the patents based on simple counts (Trajtenberg 1990). Second, there is a different propensity to patent across countries and industries due to the nature of the innovative efforts themselves or rather the opportunity of seeking patent protection in different normative contexts and market configurations (Dernis and Khan 2004). Third, as inventions are not all patentable or patented, patent statistics trivially fail to capture the overall innovative effort. Literature then also applies some alternative approaches to measure innovative activities.

As discussed in Keller (2004), one is to rely on the intensity of the Research and Development (R&D) that can be seen as a proxy for the inputs of innovative activities. Another is to focus on the improvements in the Total Factor Productivity

(TFP) to quantify the economic effects of the innovative efforts. These common indicators have nonetheless their own drawbacks too. For instance, any series of R&D expenditure is unable to account for the stochastic nature of technological change and limits to capture the "trend" component of the overall innovative effort. Furthermore, R&D information tend to be collected on shorter periods than patents' and to be available for a smaller number of countries. Productivity, on the contrary, is an indirect measure requiring substantial manipulation and estimation of economic data. In addition, it is apt to approximate more the efficacy than the diffusion of the innovative activities.

The use of patents has spread in turn due to some peculiar advantages. There are a very few examples of inventions indeed that are economically relevant and not patented (Dernis and Guellec 2001). Literature provides also evidence of a strong correlation between the number of patent applications and the volume of R&D spending (Griliches 1990). Furthermore, in some cases like China, there is evidence that patent statistics perform even better than input proxies to compare the innovative capabilities across regions (Guan and Liu 2005). Finally, other than counted to approximate the intensity, patents can be further explored their own contents to investigate the characteristics of the underlying innovative activities and then, to mitigate some of the disadvantages in patent statistics.

As an example, some patents might protect very valuable inventions while some others, on the opposite, marginal contributions with poor or even no commercial return. To deal with this heterogeneity across patent documents, literature has grown to offer more sophisticated indicators than the simple count. There are in particular two basic strategies to take account of the patent quality. One is citation-weighted count based on the assumption that more relevant patented inventions are more frequently cited in later patents (Hall et al. 2000). The other considers the extension of the patent families, that is, the number of patent documents filed at separate offices to protect the same invention, as proportional to the expected returns on innovative activity (Lanjouw et al. 1998).

Refinements and additional applications have then followed. The triadic patent family consisting of the same application at the EPO, Japanese Patent Office (JPO) and United States Patent and Trademark Office (USPTO), in particular, has become a method to remove potential geographical biases from comparative counts (Dernis and Khan 2004) and a common benchmark of the patent quality (Popp 2005). Another approach is to consider the lag between the application and grant dates (Squicciarini et al. 2013), since the applicants are expected to put a greater deal of effort in the applications they deem to have higher chances of being granted (Harhoff and Wagner 2009). Furthermore, backward citations, i.e., the patents and non-patent documents listed in the application as sources of previous knowledge, are used to account for the novelty of inventions and the flows of knowledge (Criscuolo and Verspagen 2008).

There are also more complex indicators built on the technological classification of inventions, such as the generality and the originality indexes (Trajtenberg et al. 1997) or the patent scope (Lerner 1994). Although not exhaustive, this brief survey of the patent statistics shows how much the pieces of information reported in the patent documents can be made a flexible use to approximate several aspects of the innovative activities. In the same fashion, the idea in this paper is to obtain a measure of the embeddedness from the location of applicants or inventors. Patent statistics can be built however on records from a variety of sources, i.e., different patent offices. China has its own national of course, but important advantages can arise from referring, as mentioned, to the patent documents filed at a regional office, like the European, or a well-reputed international office, like the Japanese or the United States'.

A technology "new to the country" is not necessarily "new to the world" (Li 2009). In addition, seeking protection abroad is costlier compared to applying to the home countries' offices. The patent documents filed at a regional or an internationally-reputed office are then expected to reflect inventions of higher quality and more-homogenous economic value. This holds also in the case of China (Fisch et al. 2017) and, accordingly, the analysis in this paper considers the patent applications from China to the European Patent Office (EPO) that are collected in the OECD REGPAT database and, specifically, in the edition released on January 2014. The main reason of this specific choice is in the extended details on inventors and applicants that are systematized in the database.

It has been largely motivated in literature indeed how much a region-level perspective can suit for studying innovative activities (Cooke et al. 1997, 1998) and how much region-specific features can be relevant in the case of China's (Wang and Lin 2012). The geographical information on the Chinese inventors and applicants included in the OECD REGPAT database are at a provincial level. This level sounds relatively coarse for the purposes of this paper, but the information provided in the database are detailed enough to rearrange the patent documents at a finer level. Following a well-established procedure for regionalization (Callaert et al. 2011), a semantic search of the prefectural cities' toponyms has been performed in the "address" fields associated with each inventor and applicant whose country of residence was catalogued as "China". Among them, the inventors and applicants from Hong Kong, Macau and Taiwan have been excluded, given that these locations have been not directly involved in the country's transformation considered here.

The outcome of data mining is a set of about 20,000 patent applications filed between 1981 and 2009 and distributed over 200 of 345 prefectural cities in China. These patents are those attributed to at least one inventor or applicant whose residence is recorded in China. Data have been then aggregated in a full-country wide and 30-year long panel of data by fractional count and priority year (OECD 2009).

The statistics built on these data are expected to reliably approximate the innovative activities performed across China. Some concerns may however persist on using the EPO data in place of the SIPO's. There are in fact only few patent applications to the EPO from China before 2002. Nonetheless, a low patent count at the EPO is a result per se: a weak interest in seeking protection abroad is likely due to many reasons, including that inventions may lack enough technological or commercial relevance to generate returns compensating for the opportunity cost of applying outside the national borders. In this sense, moving from null to positive counts can reveal more clearly that the local innovative activities have grown more valuable and competitive at an international level.

The reliability of referring to the EPO source in investigating the evolution of the innovative activities in China can be also tested. A study of the correlation between the applications from China to the EPO (catalogued as "China") and the SIPO (catalogued as "domestic") is presented in Appendix A. This simple empirical exercise shows that the correlation tends to be very high overall and even considering the temporal and the spatial variability separately. The tests support both the strategy of using patent statistics based on the EPO's documents and the fair convenience of excluding Hong Kong, Macau and Taiwan from the data set.

Now that an appropriate source is identified, the empirical issue is to manipulate the data to identify different levels of embeddedness the innovative activities have reached in the Chinese prefectural cities. The methodological strategy proposed here is to differentiate the patents by their own place-related features. More precisely, the analysis focuses on the distribution and combination of three indicators of intrinsic location-related patents' characteristics: the prevalence of patents with indigenous inventors (INV_{it}), indigenous applicants (APP_{it}), or both them ($BOTH_{it}$).

These indicators are built on a common denominator (tot_{it}) and three separate numerators (inv_{it}, app_{it} and $both_{it}$) obtained as a fractional count of the patent applications attributable to a given prefectural city i in year t without distinction it is because of the inventors' or applicants' location. The counting procedure is articulated in several steps. The first is to identify a set D_i of all the patent documents reporting at least one inventor or applicant whose address refers to that prefectural city. The second is to take a single document d_i in this set, to count the total number of inventors and applicant reported in the document (inv_d, app_d) and those of them located in the prefectural city i (inv_{id}, app_{id}). The third step is to calculate the prefecture-related fractions of inventors and applicants as inv_{id}/inv_d and app_{id}/app_d.

Inventors (inv) and applicants (app) can be also combined into a two-dimensional space $inv_d \times app_d$ whose size is simplified as 1×1, given that $0 \leq inv_{id}/inv_d \leq 1$ and $0 \leq app_{id}/app_d \leq 1$. Furthermore, fractional count allows to easily decompose each dimension into the sum of a local and a non-local component with the last being the complement to the counts above, i.e., $1 - inv_{id}/inv_d$ and $1 - app_{id}/app_d$. The products between the two components of inv_d and app_d can be arranged into a two-entry table to identify four elements d_{rc} in the location of a single patent document, where r is a row and c a column (Table 1).

Table 1 Two-dimensional decomposition of the dth patent' location

inv_d	app_d	
	$\frac{app_{id}}{app_d}$	$1-\frac{app_{id}}{app_d}$
$\frac{inv_{id}}{inv_d}$	$\frac{inv_{id}}{inv_d}\frac{app_{id}}{app_d}$	$\frac{inv_{id}}{inv_d}\left(1-\frac{app_{id}}{app_d}\right)$
$1-\frac{inv_{id}}{inv_d}$	$\left(1-\frac{inv_{id}}{inv_d}\right)\frac{app_{id}}{app_d}$	$1-\left(\frac{inv_{id}}{inv_d}+\frac{app_{id}}{app_d}-\frac{inv_{id}}{inv_d}\frac{app_{id}}{app_d}\right)$

The sum of the two elements in the first row of Table 1 is the fraction of local patent's inventors, i.e., $d_{11} + d_{12} = inv_{id}/inv_d$, as the same as the sum of the two elements in the first column is the fraction of local patent's applicants, i.e., $d_{12} + d_{21} = app_{id}/app_d$. Together, the four elements in the table fill the entire two-dimensional space $inv_d \times app_d$, i.e., $d_{11} + d_{12} + d_{21} + d_{22} = 1$. A portion of this space (d_{22}) is not filled however by the local inventors and applicants, so that it represents the exogenous element. On the opposite, the sum of the remaining three elements is considered as the total endogenous component $tot_{id} = d_{11} + d_{12} + d_{21}$ and taken as the basis for a common denominator to build the three indicators.

This denominator cannot be directly related to a sum of regional nor of applicant–inventor shares. The calculation of these shares would require indeed to consider also the element d_{22}, which is instead excluded here from the addends to tot_{id}. In other words, the total count of the local patent fractions tot_{id} is different from a sum of shares because $tot_{id} \leq d_{11} + d_{12} + d_{21} + d_{22}$. On the other side, it is also different from a simple count because of $tot_{id} \geq d_{11} + d_{12}$ and $tot_{id} \geq d_{11} + d_{21}$. The pair of these differences are clarified by the values tot_{id} can assume, i.e., $tot_{id} \in (0, 1]$. While $tot_{id} = 0$ is disregarded as the case that no portion of the patent's location at all is attributed to the prefectural city i, the positive values of tot_{id} increase as the fractions of local inventors or applicants in the patent document d increase. Furthermore, a few simple algebraic operations allow to find that $d_{22} = 0$ and $inv_{id} > 0$ or $d_{22} = 0$ and $app_{id} > 0$ are both sufficient conditions for $tot_{id} = 1$.

A patent is then entirely attributed to a prefectural city i if all the individuals in the set of inventors inv_d or applicants app_d are located in that city, provided at least one of the individuals in the other set is too. In all the other cases, a fraction only of the patent is attributed to city, i.e., $0 < tot_{id} < 1$. By definition, this fraction is nonetheless larger than any other based on single count. It is indeed $tot_{id} \geq inv_{id}/inv_d$ if $inv_d \geq inv_{id}$ and $tot_{id} \geq app_{id}/app_d$ if $app_d \geq app_{id}$, the pair of which conditions are always verified. Accordingly, the two-dimensional count method proposed in this paper allows a wider appreciation of the indigenous elements in the local innovative activities than single count. The empirical settings are not aimed to quantify a propensity to patent after all.

A special case occurs when the pair of inv_{id} and $app_{id} = 1$. In this case $tot_{id} = d_{11}$, that is, the overlapping between the set of indigenous inventors and applicants. This elements in the two-dimensional locational space of a patent d is named here $both_{id}$. When inv_{id} or $app_{id} < 1$, of course, the overlapping is limited to a fraction so that $0 < both_{id} < 1$. To recap, each one of the counts, let generically say x_{id}, ranges between 0 and 1 included, with the exception of $tot_{id} = 0$ being a trivial case for the moment. In particular, the two fractions $inv_{id} = 1$ and $app_{id} = 1$ if and only if the patent' inventors and applicants, respectively, are all located in the prefectural city i. Differently, the indigenous patent component is $tot_{id} = 1$ if $inv_{id} = 1$ and $app_{id} > 0$ or alternatively $inv_{id} > 0$ and $app_{id} = 1$. The overlapping between indigenous inventors and applicants is $both_{id} > 0$ if and only if the pair of inv_{id} and $app_{id} > 0$, and especially $both_{id} = 1$ if and only if the pair of inv_{id} and $app_{id} = 1$ while $both_{id} = 0$ if $inv_{id} = 0$ or alternatively $app_{id} = 0$.

These counts can be also interpreted with reference to the set theory. A single patent document d can be indeed considered as a collection of possible subsets of

$inv._d \times app._d$ elements. Among them, there are two more relevant subsets. One consists of all the combinations with the inventor *inv* located in the prefectural city *i*. The other contains all the combinations with the applicant *app* located in the same prefectural city *i*. The combinations with both the inventor *inv* and applicant *app* located in *i* populate the intersection between these two subsets, while the total count tot_{id} represents their union.

The steps above are replicated for each patent document attributed to the prefectural city *i*, i.e., $d \in D_i$. Furthermore, one additional piece of information from the patent documents, that is, the prior date, is retrieved to aggregate the patent fractions by year *t* as follows:

$$x_{\text{it}} = \sum_{d \in D_{\text{it}}} x_{\text{idt}} \tag{1}$$

where x_{id} is replaced with inv_{id}/inv_d, app_{id}/app_d, $both_{id}$ and tot_{id} to compute the three indicators' numerators (inv_{it}, $both_{it}$ and app_{it}) and the one denominator (tot_{it}). The three indicators built on these counts aim to measure how the one or the other dimension in the localization of the innovative activities add up to gain relative prominence revealing a certain level of embeddedness. Count redundancies are prevented as follows:

$$APP_{it} = (app_{it} - both_{it})/tot_{it} \tag{2}$$

$$BOTH_{it} = both_{it}/tot_{it} \tag{3}$$

$$INV_{it} = (inv_{it} - both_{it})/tot_{it} \tag{4}$$

where $tot_{it} = app_{it} + inv_{it} - both_{it}$, so that $\forall$ prefectural city *i* where $tot_{it} > 0$ in year *t*

$$APP_{it} + BOTH_{it} + INV_{it} = 1 \tag{5}$$

The values of whatever indicator X_{it}, whose distribution is presented in Fig. 4, then varies as $X_{it} \in [0, 1]$.

It should be clear that the indicators are not intended to measure how much the innovative activities are intense in each location, but rather to capture how much of the separate elements of the innovative process are located there. As discussed above, the empirical stylization proposed is that the embeddedness of innovative activities can be approximated to vary according to the prevalence of these elements. The three indicators must be considered therefore together to provide a meaningful evidence. As an example, let assume the case that the values of the indicators are $INV_{it} = 0$, $BOTH_{it} = 0.5$ and $APP_{it} = 0.5$ in a given prefectural city *i* and year *t*. Considering each indicator individually would be confounding the whole picture as it can result from alternative combinations of counts. The true one does depend also on the values taken by all the indicators. It could be indeed $INV_{it} = 0$ because no patent inventor is located in that city that year ($inv_{it} = 0$) as the same as the number of inventors is just lower than the number of patent

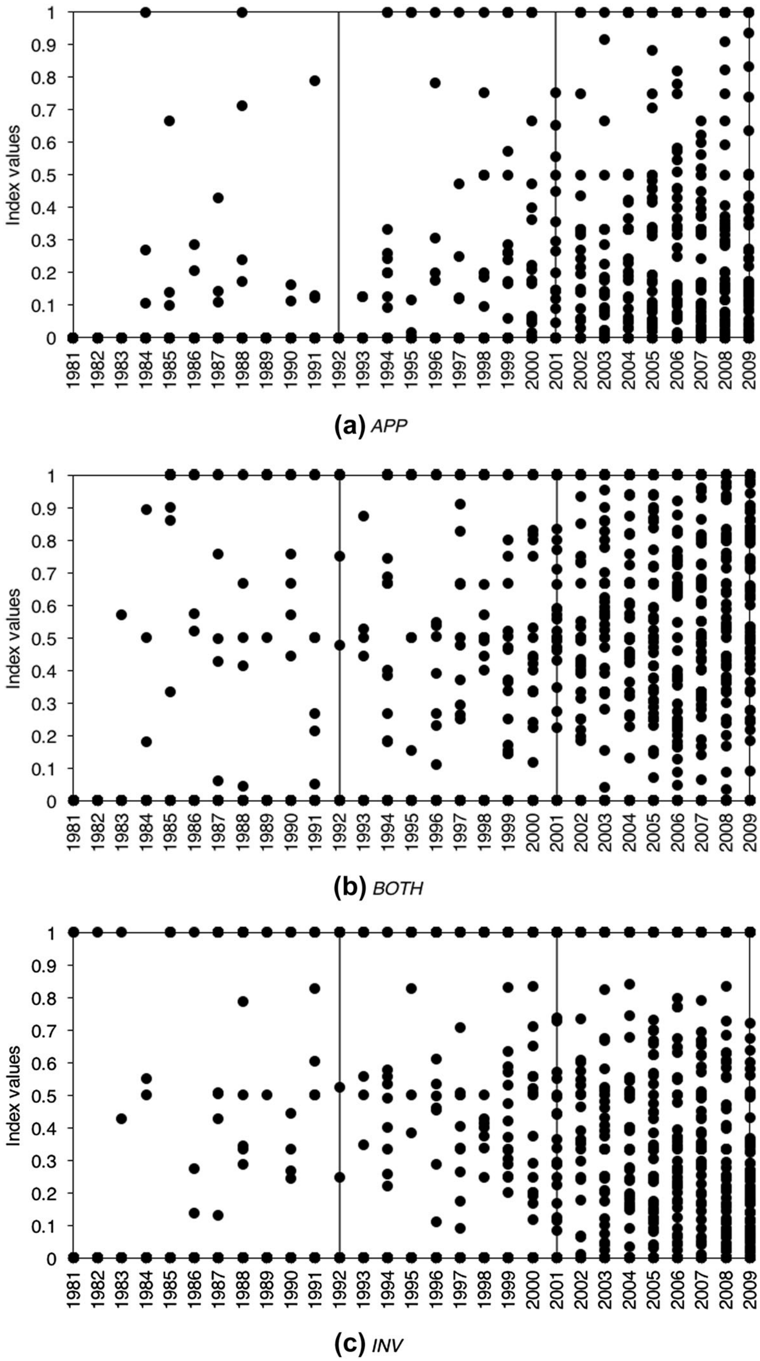

Fig. 4 Distribution of the indicators by year: Chinese prefectural cities, 1981–2009. Source: authors' arrangement from the OECD REGPAT database, January 2014

applicants ($0 < inv_{it} < app_{it}$). This is actually the case in the example, where $inv_{it} = both_{it} > 0$ and $app_{it} = tot_{it}$.

Conceptually, embeddedness is expected to increase when the opportunities to commit, fund, manage and exploit the returns of innovative activities increase. Accordingly, the analysis moves from an ideal ranking over the indicators, so that the embeddedness of the local innovative activities is assumed to increase, moving from the prevalence of the *INV*, through the prevalence of the *BOTH*, to the prevalence of the *APP* indicator. When the *INV* shows the highest value among the indicators in one location, it is supposed that the innovative activities in that location are mainly exogenously driven due to a lack of indigenous applicants. On the opposite, when it is the *APP* indicator to exhibit the highest value, it suggests that one place attracts and exploits innovative resources that are located elsewhere, capturing the return of their inventions. Finally, if the highest value is of the *BOTH* indicator, then the entire innovative chain is substantially located in the same place.

The final step is to produce a meaningful representation of these many values, that is, to compare the indicators one another within each prefectural city in any point of time and, possibly, to have insights into the similarities across the observations. Cluster analysis is an effective method to summarize multidimensional variability and identify some common patterns. This method aims indeed "to classify a sample of entities (individual or objects) into a small number of mutually exclusive groups based on their similarities" (Hair et al. 2009, p. 20).

On the practical side, observations are taken the values of each characteristic (indicator) to be grouped on their reciprocal closeness. Closeness is calculated according to a measure of distance between some representative values of the emerging groups, so that statistical inference is limited to the association between observations based on similar values. This approach is not very common in innovation studies, yet adopted in some valuable contributions on the role of capabilities in economic development. A very recent example is Fagerberg and Srholec (2017) undertaking a cluster analysis on three capability variables, including one technological, the authors have constructed to the purpose of their analysis.

Figure 4 above has shown the values of the three indicators to be broadly dispersed across observations, so that some triads of values (one for each indicator) discriminating across groups are very likely to be computed. Rather, given the large number of observations (345 prefectural cities in almost 30 years), variability could be even so exaggerated that a plain outcome is difficult to reach. In particular, it is expected that numerous yearly deviations can confound the class an observation is grouped in. For this reason, within-stage average values are preferred here to enter the clustering procedure.

Being X_{it} the yearly value of whatever indicator, its within-stage average value X_{is} is calculated as:

$$X_{\text{is}} = \frac{1}{T}\sum_{t=1}^{T} X_{\text{it}} \tag{6}$$

where T is the overall number of years t in the reform stages s drawn in Sect. 2, while i is again a prefectural city. The number of observations is consequently reduced to the values of the three indicators taken at three points in time s for each prefectural city i.

There are some advantages in such a simplification but one main setback. It is in the form of the indicators being indefinite when $tot_{it} = 0$. This issue is managed assigning a null value to all the indicators X_{it} so that they can enter the clustering procedure regardless. However, when $tot_{it} = 0 \forall\ t \in s$, i.e., a prefectural city i has not recorded any patent application for the entire period s so that $tot_{is} = 0$, then the prefectural city i is excluded ex ante from the analysis. The rationale is to do not overload the clustering procedure with redundant “noise” and let it better discriminate between groups of prefectural cities where innovative activities have taken actually place.

In practice, this means that not all the 345 prefectural cities are grouped on the emerging similarities between the indicators’ values. They are only 40, 87 and 187 respectively for the first, the second and the third stage, that is, those attributed a positive patent count $tot_{is} > 0$. The remaining prefectural cities, that is, those attributed a null patent count $tot_{is} = 0$, are grouped ex ante in a class of “no innovative activity” and retrieved at the final step of the analysis to map the countrywide picture. An alternative procedure including all the observations is reported in “Appendix B” as a robustness check. It proves that the exclusion ex ante of the null values does not substantially affect the results.

On the other hand, when $tot_{it} > 0$, the yearly values of the indicators X_{it} add up to 1. These values are accordingly unrelated to the intensity of patenting, so that they do not help consider dissimilarities related to the total number of patents across the prefectural cities. Differently, the within-stage average values X_{is} allow somehow to rescale the indicators, with respect to the persistence of the innovative activities in prefectural cities all along the period considered. Individual values X_{is} entering the clustering procedure are indeed increasing in every tth $X_{it} > 0$. This holds regardless of the prefectural patenting history is discontinuous as the missing values are replaced by null ones for those prefectural cities where $tot_{i\tau} > 0$ for at least 1 year$\in s$. Furthermore, within-stage average values X_{is} may mitigate the randomness of values due to eventual very low patent counts tot_{it} entering the indicators as the denominators. This issue should be remembered from Sect. 2 as particularly relevant before the mid-1990s.

Despite this mitigation and the exclusion of the null values, the country’s average of the within-stage indicators is notably different across periods and substantially increasing in time (Fig. 5). The empirical solution adopted here to transform the data is therefore expected to do not bias the analysis, but rather to improve the quality of the results and to better discriminate between the different levels of embeddedness reached by the innovative activities in the Chinese prefectural cities. Furthermore, although detaching some properties of the innovative activities from a propensity to patent is quite difficult when patent statistics are used as an approximation, the indicators presented here appear theoretically robust to this issue. Given it enters the indicators as the denominator, the total prefectural count $tot_{it} > 0$ loses indeed statistical relevance as the number of patents increases.

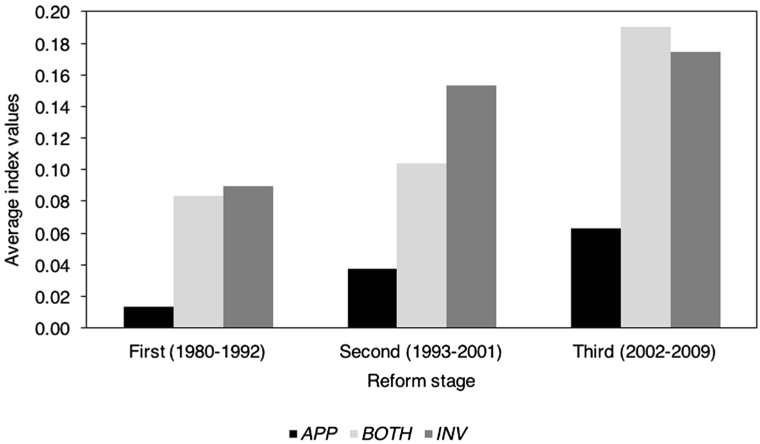

Fig. 5 Country's average of the within-stage indicator values (excluding the null values). Source: authors' arrangement from the OECD REGPAT database, January 2014

4 The embeddedness of innovative activities in the Chinese prefectural cities

This section reports and discusses the results obtained from the clustering procedure. To recap, three indicators have been built on the locations of the EPO patents' inventors and applicants in the Chinese prefectural cities. These indicators are intended to capture one element each of the local innovative process, which are supposed to link with different levels of embeddedness. The indicators based on positive patent counts are taken their within-stage average values to enter a clustering procedure performed separately for the three reform stages to classify the prefectural cities into meaningful groups.

On a more technical side, a two-step clustering procedure is performed: the results from a first hierarchical step are used as the initial seeds in a second non-hierarchical procedure (Hair et al. 2009). The squared Euclidean distance is set as measure and the average distance as grouping method. A specific cluster solution is chosen when it is associated with a significant leap between the values of the clustering coefficients, i.e., the measures of the observations' tendency to cluster together in a progressive number of groups (Manly 2004). Tables 2, 3 and 4 report the values of the centroids, that is, the central representative observations, and the final number of cases for the cluster solutions chosen in each period.

The first hierarchical step suggests both a seven- and an eight-cluster solution for the first stage, but the seven one, which is associated with a clustering coefficient increasing from 2.3 to 5.4, sounds easier to interpret. Differently, there are a clearly identifiable six-cluster solution for the second stage and a five-cluster solution for the third, whose clustering coefficients respectively jump from 4.9 to 6.4 and from 5.5 to 7.8 after a smooth increase.

The centroids obtained are then reintroduced in the clustering procedure as the initial seeds of the second K-means non-hierarchical step reassigning the

Table 2 Clusters' description: centroids and number of cases, first reform stage (1981–1992)

	Clusters							Total
	I	II	III	IV	V	VI	VII	
Cases	2	23	1	2	1	5	6	40
Centroids								
APP	0.043	0.008	0.100	0.046	0.046	0.000	0.001	
BOTH	0.283	0.028	0.400	0.266	0.192	0.046	0.126	
INV	0.019	0.043	0.422	0.224	0.452	0.169	0.064	

Table 3 Clusters' description: centroids and number of cases, second reform stage (1993–2001)

	Clusters						Total
	I	II	III	IV	V	VI	
Cases	7	11	1	3	50	15	87
Centroids							
APP	0.072	0.044	0.227	0.041	0.029	0.031	
BOTH	0.335	0.232	0.528	0.154	0.040	0.075	
INV	0.416	0.106	0.244	0.581	0.067	0.256	

Table 4 Clusters' description: centroids and number of cases, third reform stage (2002–2009)

	Clusters					Total
	I	II	III	IV	V	
Cases	14	5	16	114	38	187
Centroids						
APP	0.113	0.406	0.033	0.032	0.102	
BOTH	0.659	0.264	0.193	0.056	0.406	
INV	0.164	0.079	0.538	0.106	0.241	

observations to each group by following iterations until the best performing separation is reached (Hair et al. 2009). This allows to optimize the analysis as the K-means non-hierarchical approach is more flexible than the standard hierarchical technique, but the dilemma of choosing proper initial seeds for a non-hierarchical method is contextually solved by the centroids the first step has produced.

As Tables 2, 3 and 4 report, innovative activities in the Chinese prefectural cities exhibit two additional tendencies to the exponential increase and the spatial concentration shown in Sect. 2. First, the values of the centroids increase stage by stage. It means that, although the impressive surge of patent applications to the EPO from China is primarily due to the effort in a few regions, the average intensity of patenting has more diffusely grown over time, including in some of the lower-performing regions. In this sense, the results replicate the evidence shown above in Fig. 2, but they now highlight a clear transitional process at the local level.

Second, the number of groups decreases over time. It is evident that some clusters include one or two cases only in the first period, but the overall reinforcement of the local innovative activities is clear. The high concentration of innovative activities during the first reform stage is primarily due to a very low number of patent applications to the EPO, so that just a few observations are isolated rather than grouped. Later in the third reform stage, more intense innovative activities allow instead data to effectively cluster and highlight more consistent differences across groups.

The results suggest that innovative activities in the Chinese prefectural cities have diffused and grown in intensity, but they do not have provided proper evidence on embeddedness for now. It is indeed difficult to infer on inhomogeneous sets of groups. For this reason, the groups returned by the clustering procedure for each stage are converted into a unique descriptive framework based on the results obtained for the third period, where the separation is clearer. The final framework is structured into six new groups named "adjusted clusters" (ACL) that cover the complete range of the indicators' combinations (Table 5).

More precisely, some of the groups in the first and second stage are merged together according to the closeness of their centroids so that the distance between the new groups is more pronounced. This leads to identify four "adjusted clusters" among the results of the clustering procedure, where the prevalence of one or a couple of indicators is quite evident. Moreover, two additional "adjusted clusters" are generated to complete the description: one empty group refers to the exclusive prevalence of the *APP* indicator, while the other includes those prefectural cities having not entered the clustering procedure because of $tot_{is} = 0$. Finally, the "adjusted clusters" are ranked and progressively numbered from the ACL0 ("no innovative activity") to the ACL5 (prevalence of the *APP* indicator only), based on the assumption that the gains of embeddedness progress from the prevalence of indigenous inventors (*INV*) to the prevalence of indigenous applicants (*APP*).

Table 5 Table of results converted into adjusted clusters (ACL)

Adjusted clusters		Clusters obtained from the procedure			Number of grouped cases		
Code	Description	Reform stage			Reform stage		
		First	Second	Third	First	Second	Third
ACL0	No activity (not included)				305	258	158
ACL1	Prevalence of *INV*	II, V, VI	IV, V, VI	III, IV	29	68	130
ACL2	Prevalence of *INV* and *BOTH*	III, IV	I	V	3	7	38
ACL3	Prevalence of *BOTH*	I, VII	II, III	I	8	12	14
ACL4	Prevalence of *BOTH* and *APP*			II	0	0	5
ACL5	Prevalence of *APP*				0	0	0

As discussed above, the prevalence of the *INV* indicator in certain regions means that, in these regions, the innovative process mainly depends on exogenous initiatives, as the command over the process and the returns on innovation is located elsewhere. Conversely, higher values of the *BOTH* indicator suggest that the innovative chain is more structured locally. Last, the prevalence of the *APP* indicator let suppose one step further towards capturing and anchoring the innovative activities locally, and the capability to also gain from processes located elsewhere.

There is no group exhibiting the prevalence of the *APP* indicator until the third stage, and it happens only together with the *BOTH* indicator (ACL4). This evidence confirms that innovative activities have effectively grown to be more embedded in some of the Chinese prefectural cities than in others. Contextually, the number of prefectural cities where the *BOTH* indicator only prevails (ACL3) increases, including those regions where perhaps the groundwork for having innovative processes that are locally well-structured is substantially laid, but further development is required to gain a leadership in the knowledge-based economy.

On the other side, the number of prefectural cities whose inventors' patents are filed at the EPO increases importantly over time, populating the group in which the *INV* indicator prevails (ACL1) with 29–130 cases between the first to the third period. Such a diffusion of exogenously-driven innovative activities is then complemented by a number of prefectural cities moving into the group where, during the third stage, innovative capabilities have become more emancipated and the *INV* indicator prevails together with the *BOTH* one (ACL2).

The results therefore reveal two complementary phenomena that the maps in Figs. 6a–c can help to grasp. First, innovative activities have diffused across prefectures relying on exogenous seeds (ACL1 and ACL2) and, second, the local innovative processes have later reached to be more structured and embedded in a few prefectures (ACL3 and ACL4). Accordingly, the "adjusted clusters" presented here provide a consistent picture of the transitional process behind the diffusion of the innovative activities in China. The "dualism" returned by the analysis that couples with other dual dynamics in the country plays indeed its own role in this transition, which is sustained by an impressive growth of the innovative activities but also by evident disparities in how they are structured locally (Li 2009).

Coherently with the path started when the country's transition from a planned to a market economy was decided at the late-1970s, innovative activities were concentrated in a few very populated and strategically located cities at the early stage of this China's new economic-development pace. Innovative activities then started increasing and diffusing during the second stage, especially in the Coastal area, and the overlapping between industrial and technological development has become evidently self-reinforcing in these regions (Liu and Sun 2009). This was just anticipating what will have been even more robust in the last stage. The surge of prefectures from which patents are applied to the EPO has been indeed impressive after 2001. Nonetheless, the linkage between this progression and the achievement of higher level of embeddedness is less clear.

With very few exceptions such as Chongqing, the "adjusted clusters" ACL3 and ACL4, in which the *BOTH* indicator prevails alone or together with the *APP*

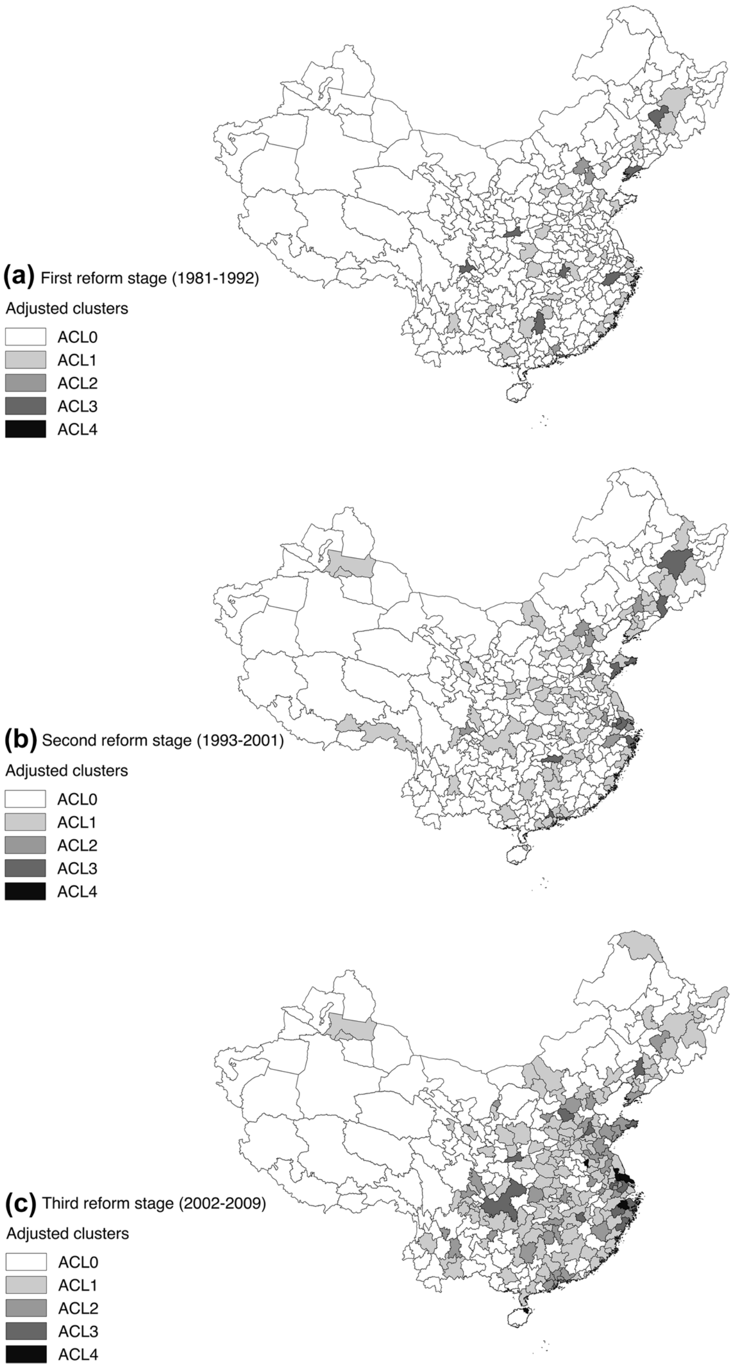

Fig. 6 Geographical distribution of the adjusted clusters by reform stage: Chinese prefectural cities

indicator, they include prefectural cities located in the Coastal area. In this sense, also the embeddedness the innovative activities have gained in China quite overlaps with the wider country's developmental scenario. It is indeed obvious that having grown to be more and more used to the innovative activities may have allowed some locations to improve the properties of their innovative environments.

Embeddedness, which is one of the most important properties of these environments (Boschma 2005; Cooke 2005; Maskell and Malmberg 1999; Torre and Rallet 2005), is however something more than the product of self-reinforcing routines. Especially along with economic catching up, like in the case of China, embeddedness can crucially depend also on the efficiency of the innovative process and some targeted incentives to effort and upgrading (Li 2009, 2012), on a solid absorptive capacity (Asheim and Vang 2011; Lau and Lo 2015), and on structuring at levels beyond the individual company (Srholec 2011). Conceptually, all these elements should have a local nature. So, the question here is whether the exogenous seeding of development, and consequently of innovative activities, may have had relevant effect on the innovative activities to gain embeddedness in some locations.

To answer this question, a more qualitative evidence is required. Some regions have been previously mentioned in the paper as they are exemplificative places of exogenous seeding (the SEZ). Table 6 compares the distribution of cases (prefectural cities) over the "adjusted clusters" in these regions to the distribution of cases in other Coastal regions.

Although they are mainly concentrated in the groups where the *INV* indicator only prevails (ACL1), the SEZ-hosting prefectural cities have been assigned to several groups since the first reform stage, yet including the one in which the *BOTH* indicator prevails (ACL3). These cities also show the lowest rate of "no innovative activity" at the EPO (ACL0), compared to other regions in the period 1981–1992. In addition, several cities have fast moved towards more structured local innovative environments (ACL2 and ACL3) between the first and second stage.

This rapid restructuring dynamic is consistent with the role of the SEZ as "doorways" to upgraded industrial and innovative capabilities. Nonetheless, there is less appreciable evidence of embedding in the transition of the SEZ-hosting cities from the second to the third stage, during which other regions, such as Fujian, Guangdong, Jiangsu and Zhejiang, are showing on the opposite the most relevant achievements in developing their local innovative environments. In these regions, innovative activities were no doubt amongst the weakest in China before 1993, mostly entering the group of "no innovative activity" (ACL0), if the SEZ-hosting cities are excluded. They even show a slower transition to the higher-ranked "adjusted clusters" between the first and second stage, but some of them have clearly furthered their innovative activities to gain embeddedness at the third stage, so that they reached the group where the *APP* and the *BOTH* indicators prevail together (ACL4).

Exogenously-seeded innovative activities then appear to have delayed gaining embeddedness compared to those located in other Chinese prefectural cities. In other words, exogenous seeding has enabled an early fast diffusion of the innovative activities but somehow also crowded out or at least hindered the more indigenous of them from emerging as prominent within the local innovative environment. This

Table 6 Frequency of cases in the adjusted clusters by reform stage: selected groups of Chinese prefectural cities (percentage share)

Adjusted clusters	Frequency		
	Reform stage		
	First (1981–1992)	Second (1993–2001)	Third (2002–2009)
Special economic zones[a]			
ACL0	28.6	14.3	14.3
ACL1	42.9	28.6	28.6
ACL2	14.3	28.6	28.6
ACL3	14.3	28.6	28.6
ACL4	0.0	0.0	0.0
ACL5	0.0	0.0	0.0
Fujian[b]			
ACL0	75.0	75.0	12.5
ACL1	25.0	25.0	75.0
ACL2	0.0	0.0	12.5
ACL3	0.0	0.0	0.0
ACL4	0.0	0.0	0.0
ACL5	0.0	0.0	0.0
Guangdong[c]			
ACL0	88.9	61.1	27.8
ACL1	5.6	33.3	38.9
ACL2	5.6	0.0	33.3
ACL3	0.0	5.6	0.0
ACL4	0.0	0.0	0.0
ACL5	0.0	0.0	0.0
Jiangsu			
ACL0	92.3	53.8	0.0
ACL1	7.7	23.1	38.5
ACL2	0.0	7.7	30.8
ACL3	0.0	15.4	15.4
ACL4	0.0	0.0	15.4
ACL5	0.0	0.0	0.0
Zhejiang			
ACL0	72.7	54.5	0.0
ACL1	18.2	27.3	45.5
ACL2	0.0	9.1	18.2
ACL3	9.1	9.1	27.3
ACL4	0.0	0.0	9.1
ACL5	0.0	0.0	0.0

[a]Including Hainan, Shanghai, Shantou, Shenzhen, Tianjin, Xiamen and Zhuhai

[b]Excluding Xiamen

[c] Excluding Shantou, Shenzhen and Zhuhai

picture is coherent with the long-term development process summarized in Sect. 2, although it is for sure that having isolated all the SEZ-hosting prefectural cities from the wider regions they are part emphasizes the evidence presented in Table 6. The SEZ were indeed self-propelling their own development but also the spillovers from these locations have contributed to develop the innovative environment in some of the surrounding cities. The SEZ-hosting cities are often situated in the same region (province) of many other industrialized cities on the Coast, like in the case of Guangdong (Shantou, Shenzhen and Zhuhai) and Fujian (Xiamen). In other cases, regions are instead proximate to the SEZ-hosting cities, like Jiangsu and Zhejiang (Shanghai), or to other cities not considered here, such as Hong Kong (Guangdong). Therefore, regardless of a late transitional stickiness in the SEZ, the strategy of having opened just these very "doorways" to a market-based development at the beginning, it appears to have effectively worked to promote overall economic growth in the long term, as well as the diffusion and the embeddedness of the innovative activities also in some other prefectural cities.

5 Concluding remarks

This paper has summarized the main steps in the long-term developmental strategy having supported China's growth and transition since 1978 onwards. The focus has been foremost on two devices aimed to promote industrial upgrading: attracting foreign capitals and technologies in the SEZ (exogenous seeds) on one hand, and favoring business to cluster around more endogenous seeds, such as industrial and technological development parks, on the other. These two devices have been supposed also as relevant to the diffusion and embeddedness of innovative activities. The research question was if exogenous seeding, although having favored the diffusion of innovative activities, can have delayed them to gain embeddedness.

The paper has attempted to answer this question empirically, based on the approximation of the innovative activities with the EPO's patent applications from the Chinese prefectural cities, and a tentative stylization of separate levels of embeddedness with respect to the location of patents' applicants and inventors. Moving from these postulations, three indicators have been built to enter a clustering procedure classifying the observations into groups, separately for the three stages identified along the country's developmental pace.

The analysis has returned the Chinese prefectural cities clustered into a period-varying number of groups that have been rearranged to obtain a homogenous between-stage interpretative framework. This framework has provided evidence of a growing diffusion and embeddedness of the innovative activities stage-by-stage. More in details, innovative activities result to have reached deeper embeddedness since the early-2000s (third stage) but qualitative discussion has revealed that this has happened mainly in a few locations that do not include the SEZ-hosting cities. The research question has been then given positive answer.

Nonetheless, no formal test of the linkages between the level of embeddedness and the nature of "seeding" has been presented in this paper. In other words, the empirical exercise substantially remains at an explorative stage, which represents its main limitation. It no doubt means that there is still much to do on the empirical side. Additional elements can be included to refine the analysis, such as the fields the local innovative activities are specialized, the private or public nature of the innovators, and the range and direction of potential spillovers. Little official statistics are unfortunately collected for the Chinese prefectural cities before the mid-1990s, but the literature proposes other indicators built on patent statistics that can serve as a complement to those presented in this paper. The indicators of the technological regime (Breschi et al. 2000) or the accomplishments in technological catching-up (Park and Lee 2006) can be indeed taken to test, for instance, where separate levels of embeddedness positively contribute to qualifying the development of the local innovative environment. Further research is right expected to be fruitfully focusing on investigating this linkage after an appropriate effort in data mining and modelling.

At the moment, this paper gives quite clear insights however into the local innovative activities having delayed gaining embeddedness where exogenous seeds were stronger. In this sense, some promising pieces of evidence have been already reached. This evidence concerns one of the possible secondary effects of a popular strategy to foster catching up with industrialization in developing countries. Accordingly, the paper strives for contributing primarily to the debate in development economics and, in particular, that on the relevance of the innovative and technological capabilities. Formerly discussed in Abramovitz (1986), this topic has received renewed attention in literature since the unprecedented growth experienced by China and a few other Asian countries before, breeding outstanding empirical works like Lee (2013) on the middle-income trap or Rodrik (2016) on premature deindustrialization. Although much more modestly, this paper has dealt with another face of the phenomenon, that is, the complex dynamic of capability building discussed in Lall (1992). The main message to the policymakers and practitioners in economic development is that exogenous seeding is an effective strategy to foster indigenous innovative activities but these very activities may take decades to emerge as connotative of the local innovative environment. Embedding could be faster in the surrounding regions if appropriately supported by complementary activities.

The paper has offered also a little contribution to the empirics of innovation. To the author's knowledge, the data set used here is one of those enabling the finest countrywide geographical study of the innovative activities in China. Albeit limited to the EPO's patent applications, the data set has been purposefully rearranged from the OECD REGPAT database (January 2014) to include the information on the prefectural location of all the Chinese applicants and inventors between 1981 and 2009. In addition, an original approach to the use of patent statistics has been presented to measure the embeddedness of the innovative activities. Despite of the room for improvement, this very approach was essential to answer the research question.

The answer is not exclusively relevant to China. It rather concerns many developing and emerging economies whose industrial upgrading has been boosted relying, at least in part, on attracting exogenous capabilities through inward foreign investment flows. It is well-known in literature how this kind of strategy can significantly strengthen catching up (Lall 1992). It is however less clear how this strategy may turn into a “trap” of dependence on exogenous forces and how long it can take to escape it. The paper has shown that the mark of exogenous seeding can last several decades, even in those countries where the economic transformation has been impressively fast like in China.

More specifically to China, this rapid transformation has produced unresolved disparities across regions (Frattini et al. 2017). Despite innovative activities appear less embedded in the prefectural cities of the “miracle” economic growth, they strongly concentrate in these “supercenters” (Crescenzi et al. 2012), so that the exiting gaps are even more difficult to fill. It is not by chance that the Chinese government is focusing on cutting disparities between the Costal and the Internal China since the late-1990s. Regional programs of coordinated development have been launched to tackle the structural sources of lags. Among other goals, they have a common focus on technological upgrading (Tian 2004) pairing with mitigating the competition between local authorities (Li and Wu 2012). The last has indeed contributed to fostering its own the more recent surge of patent applications from those cities where institutional capabilities and provisions are stronger (Hu and Jefferson 2009; Li 2012). This paper suggests that favoring the innovative activities to embed locally could help filling those gaps in the long term.

This issue is however expected to be less binding today than before, given the achievements in the most developed of the Chinese domestic regions. Domestic latecomers are indeed given the opportunity to import innovative capabilities from domestic donors making the seeding somehow “less exogenous”. In this sense, a new chapter has begun in the China’s developmental pace. As mentioned, the country has become a “world’s factory” (Ma et al. 2009) and Chinese native companies have reached the leadership in some industries (Zhang and Zhou 2015). The national government has accordingly revised its strategy and launched “Made in China 2025” in 2015, a policy program aimed to extensively support further industrial upgrading and climbing up the global value chains, especially in a number of priority sectors, such as advanced ICT, automation, power equipment, new materials and health (Kennedy 2015).

The excellence formerly targeted in the “Medium- and Long-Term Plan for Science and Technology Development (2006–2020)” (Liu et al. 2011) has then found a proper counterpart into the governmental approach to industrial development, also strengthening the linkage between the S&T and manufacturing systems. When not indigenously available, the sources of this excellence have meanwhile continued and probably will not stop being sought abroad but, it should be clear, in a completely different fashion from that narrated in this paper. Native companies have actually engaged in several cross-border M&A in industrialized countries (Deng 2009; Nam and Li 2013), growing internationally connected and investing in strategic assets to follow the shift from the initial “Open Doors” to the “Go Global” ambition noted at the early-2000s (Bellabona and Spigarelli 2007). According to the arguments discussed above, relevant research questions would investigate in which extent these new innovative capabilities abroad can be defined exogenous and how this strategy of asset-seeking affects the process they are absorbed and transferred to the homeland. Unfortunately, the answers to these questions are far beyond the scope of this paper.

Appendix A: Patent filings at the EPO and the SIPO compared

The EPO and SIPO patent statistics are here compared to give insights into the reliability of using the EPO data to approximate the innovative activities in China. The source of the SIPO statistics is the China Data on Line, Yearbooks Database providing information at the provincial level since 1985 onwards. The comparison is then necessarily performed on a shorter period (1985–2009) and broader units (provinces) than those considered in the analysis above. The overall correlation between the year–province counts from the two sources is 0.61, that is, strong. Tables 7 and 8 go more in depth reporting the counts of patent applications at the SIPO and the EPO per applicant, their relative size and correlation, based on the temporal and regional variability respectively. With a few exceptions, and despite a much lower number of patent applications at the EPO, correlations between the number of documents filed at the EPO and the SIPO tend to be very strong also over time and regions separately. This result suggests that referring to the EPO patent

Table 7 Correlation between the number of patent applications to the EPO and the SIPO by Chinese province: applicants, variability over years, 1985–2009

Province	SIPO documents	EPO documents	EPO/1000 SIPO documents	Correlation over years
China	4,828,786	23,563	4.88	0.99
Guangdong	757,272	6847	9.04	0.95
Jiangsu	603,856	473	0.78	0.95
Zhejiang	499,642	411	0.82	0.99
Shandong	367,091	211	0.58	0.97
Shanghai	348,893	680	1.95	0.97
Beijing	316,762	1,317	4.16	0.98
Liaoning	204,649	120	0.59	0.92
Sichuan	165,665	107	0.64	0.86
Hubei	142,096	88	0.62	0.93
Henan	124,651	31	0.25	0.72
Tianjin	123,289	109	0.89	0.87
Hunan	121,310	101	0.83	0.83
Fujian	112,683	135	1.20	0.90
Hebei	96,541	53	0.55	0.82
Heilongjiang	84,719	17	0.20	0.40
Shaanxi	79,060	100	1.26	0.95
Anhui	64,791	46	0.70	0.86
Chongqing	61,462	59	0.97	0.85
Jilin	59,861	41	0.68	0.50
Jiangxi	40,785	41	1.01	0.83
Guangxi	40,304	11	0.26	0.47
Shanxi	39,386	19	0.47	0.60
Yunnan	37,036	11	0.30	0.73

Table 7 continued

Province	SIPO documents	EPO documents	EPO/1000 SIPO documents	Correlation over years
Guizhou	26,755	18	0.68	0.37
Xinjiang	24,868	11	0.42	0.73
Inner Mongolia	23,746	17	0.72	0.56
Gansu	19,843	14	0.68	0.25
Hainan	8603	14	1.66	0.42
Ningxia	8482	10	1.18	0.81
Qinghai	4053	1	0.25	0.38
Tibet	1086	5	4.60	− 0.23

Table 8 Correlation between the number of patent applications to the EPO and the SIPO by year: applicants, variability over Chinese provinces, 1985–2009

Year	SIPO documents	EPO documents	EPO/1,000 SIPO documents	Correlation over provinces
1985	9411	108	11.44	0.80
1986	8945	83	9.27	0.51
1987	14,315	105	7.30	0.49
1988	7328	114	15.58	0.51
1989	27,367	130	4.74	0.71
1990	36,585	154	4.20	0.52
1991	45,395	176	3.88	0.63
1992	61,788	190	3.07	0.58
1993	68,153	168	2.46	0.62
1994	67,807	172	2.54	0.61
1995	68,880	171	2.49	0.48
1996	39,725	207	5.20	0.52
1997	90,071	259	2.88	0.50
1998	96,233	350	3.63	0.44
1999	109,958	468	4.26	0.54
2000	140,339	555	3.95	0.78
2001	165,773	779	4.70	0.87
2002	205,544	1022	4.97	0.86
2003	251,238	1222	4.86	0.87
2004	278,943	1503	5.39	0.85
2005	383,157	2178	5.68	0.79
2006	470,342	2442	5.19	0.78
2007	586,734	3209	5.47	0.68
2008	717,144	3270	4.56	0.56
2009	877,611	4531	5.16	0.52

applications is statistically, not only conceptually, robust to approximate the diffusion and the features of the innovative activities in China.

Appendix B: Robustness

This appendix presents an alternative clustering procedure to that presented in Sect. 4 to check that excluding ex ante those prefectural cities where $tot_{is} = 0$ does not lead to biased results. The procedural amendment here concerns just the treatment of the null values, now much more numerous, so that the number of observations is the same (200) in each period. Null values necessarily have a negative impact on the country's average of the within-stage indicators, especially in the first and second stages (Fig. 7). Despite this "lowering" effect of the amendment, the results obtained here are expected to be very alike those presented in Sect. 4, except they now comprise a wide group of prefectural cities whose centroids' values are much closer to zero. The size of this additional group is however expected to decrease over time.

For the remainder, the clustering procedure follows the same steps as in the main analysis. The first (hierarchical) step suggests a clearly identifiable eight-cluster solution for the first stage and a five-cluster solution for the third (the clustering coefficients jump from 9.4 to 20.6 and from 5.7 to 8.4 respectively). Differently, the proposed solution is not unique for the second stage, but a six-cluster solution is preferred to a seven- one for its simpler interpretability. Then, the centroids obtained by the first step are taken as the initial seeds in the second (K-means non-hierarchical) step generating the results shown in Tables 9, 10 and 11.

As expected, a new group of prefectural cities has emerged, notably in the period 1981–1992 (Table 9, VII). Centroids' values in this group are very low so that it tends to largely overlap with the prefectural cities of "no innovative activity" in

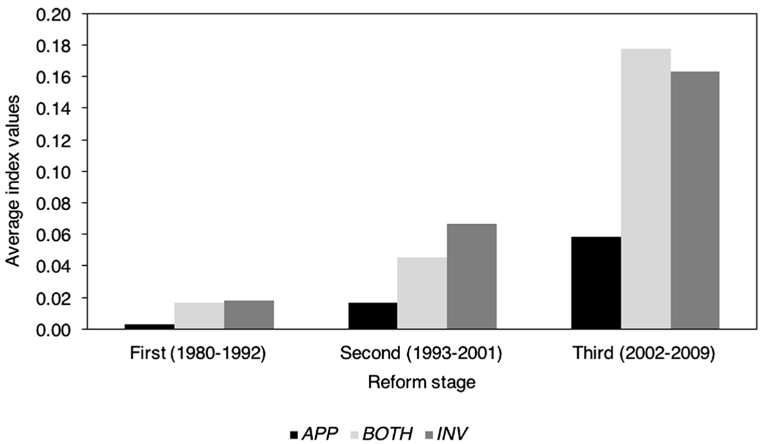

Fig. 7 Country's average of the within-stage indicator values (including the null values). Source: authors' arrangement from the OECD REGPAT database, January 2014

Table 9 Clusters' description including the null values: centroids and number of cases, first reform stage (1981–1992)

	Clusters								Total
	I	II	III	IV	V	VI	VII	VIII	
Cases	2	13	1	1	5	1	176	1	200
Centroids									
APP	0.043	0.004	0.100	0.046	0.000	0.093	0.000	0.000	
BOTH	0.283	0.098	0.400	0.192	0.046	0.251	0.000	0.282	
INV	0.019	0.032	0.422	0.452	0.169	0.192	0.005	0.256	

Table 10 Clusters' description including the null values: centroids and number of cases, second reform stage (1993–2001)

	Clusters								Total
	I	II	III	IV	V	VI	VII	VIII	
Cases	155	7	5	15	5	13			200
Centroids									
APP	0.007	0.139	0.049	0.019	0.091	0.005			
BOTH	0.007	0.151	0.228	0.189	0.391	0.064			
INV	0.016	0.216	0.565	0.087	0.361	0.254			

Table 11 Clusters' description including the null values: centroids and number of cases, third reform stage (2002–2009)

	Clusters								Total
	I	II	III	IV	V	VI	VII	VIII	
Cases	14	5	15	127	39				200
Centroids									
APP	0.113	0.406	0.032	0.029	0.100				
BOTH	0.164	0.079	0.541	0.095	0.247				
INV	0.659	0.264	0.176	0.051	0.407				

Sect. 4. Furthermore, three results here confirm those returned by the main analysis. First, the centroids' values increase stage-by-stage, which is coherent with the distributional pattern previously shown. Second, the number of groups decreases over time, so that a broad reinforcement of the innovative activities is again verified. Finally, also the number of prefectural cities where innovative activities are poorly embedded locally decreases over time.

An alternative clustering procedure including the null values therefore supports the substance of the evidence returned by the main analysis in Sect. 4. The quality of this evidence is nevertheless weakened here by the observational noise due to many null values, which prevents to clearly discriminate between the prefectural cities with "no innovative activity" and those where the *INV* indicator prevails.

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