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MORE THAN BRIC-À-BRAC: TESTING CHINESE EXCEPTIONALISM IN PATENTING BEHAVIOR USING COMPARATIVE EMPIRICAL ANALYSIS

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ABSTRACT

Although many developing economies are increasingly influencing the global economy, China's influence has been the greatest of these by far. Once hindered from competition by political and economic restrictions, China is now a major economic player. As China's economic might has grown, so too has the demand for intellectual property protection for technologies originating from China.

In this article, we present a detailed empirical study of Chinese patenting trends in the United States and the implications of these trends for the global economy. We compare these trends to patenting trends from earlier decades. Specifically, we compare Chinese patenting trends to Japan, South Korea, Brazil, Russia, and India. We study how patent allowance rates for Chinese patent applications at the United States Patent and Trademark Office have improved, and how these allowance rates compare to allowance rates in earlier "boom" periods from other East Asian countries.

While many believe that China is an exception in many respects, we find that patents for innovations originating from China seem to track a well-trodden path laid down by countries like South Korea in earlier decades. As a historical matter, we show empirically that China's patenting trend is not unique. It is instead strikingly similar to the patenting trends of other Far East Asian countries whose inventors have applied for patents in the United States. In other words, Chinese innovation is moving up the value chain in product development much like other Far East Asian countries have done in the past. We also find that

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China appears to be setting itself apart from other BRICS (Brazil, Russia, India, China, and South Africa) countries in successfully seeking patent protection for technological innovation and in producing products with higher levels of technological sophistication and innovation.

Our empirical results can be largely explained by four factors. First, our work underscores the role of foreign direct investments by multinational corporations in China; foreign direct investments are a major factor driving U.S. patent filings from China. Second, Chinese government policies have promoted patent protection and aligned Chinese patent office procedures with the procedures of the U.S. Patent and Trademark Office. Third, investment in research and development in China by both domestic and foreign entities has increased significantly. Fourth, the Chinese government has committed to moving up the value chain in products and services.

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INTRODUCTION

By all accounts, China has become a trail-blazing world economic power in the early 21st Century. Adjusting for purchasing power parity ("PPP"), China's gross domestic product ("GDP") per capita increased by 240% from 2000 to 2011. This growth has coincided with a significant increase in demand for intellectual property protection on the Chinese mainland, particularly for the patenting of new inventions. Between 2000 and 2011, the number of patent applications from Chinese residents to China's State Intellectual Property Office ("SIPO") skyrocketed from 25,346 to 415,829, increasing by an average annual rate of 29 percent.[1] SIPO currently receives more patent applications than any other patent granting authority, and 80 percent of all applications to SIPO come from Chinese residents. By way of comparison, slightly fewer than 50 percent of all applications to the U.S. Patent and Trademark Office ("USPTO") come from U.S.-based inventors.[2]

This growth in patenting represents a new reliance on technological development. Large and medium-sized enterprises in high-technology industries have submitted patent applications to SIPO at an average annual growth rate of 38 percent over the same period, increasing from 2,245 to 77,725.[3] Technological development has also changed the way Chinese businesses compete on the global stage. Instead of relying solely on manufacturing, the Chinese economy is growing and becoming more dominant through advancements in technology.

Thomas Friedman's groundbreaking work, *The World is Flat*, described how advancements in technology have increasingly globalized society and the marketplace. As technology "flattens the world," allowing new players to compete in the marketplace, three billion people who were once frozen

1. *Statistical Country Profiles: China*, WORLD INTELLECTUAL PROP.ORG., http://www.wipo.int/ipstats/en/statistics/country_profile/profile.jsp?code=CN (last visited Nov. 6, 2015).

2. *U.S. Patent Statistic Chart Calendar Years 1963 - 2014*, UNITED STATES PATENT AND TRADEMARK OFFICE, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/us_stat.htm (last visited Nov. 17, 2015) (showing foreign origin percent share in utility patent grants by year).

3. *2012 Statistics Yearbook on High Technology Industry*, CHINA NAT'L BUREAU OF STATISTICS, NAT'L DEV. & REFORM COMM'N & MINISTRY OF SCI. & TECH., http://www.stats.gov.cn/tjsj/ndsj/2012/html/U2054E.htm (last visited Nov. 6, 2015). The high technology industries include the manufacture of medicines, aircrafts and spaceships, electronic and communication equipment, computers and office equipment, medical equipment, and measuring instruments.

out of global competition are now able to enter the playing field.[4] These individuals were formerly blocked from competition because they lived in countries with closed economies and strict, hierarchical political and economic structures.

The Chinese people are among those now free to compete. Because of Friedman's "triple convergence" (new players, on a new playing field, developing new technologies), China is becoming a major economic force. No longer forced to rely on "the ponderous deliberations of finance ministers,"[5] Chinese patentees are free to make major impacts on the global economy with their individual tech-based inventions. Chinese influence will continue to grow as international patent authorities increasingly approve Chinese patent applications and aid in the enforcement of Chinese patents.

Increased global competition means that patent systems all over the world no longer operate in isolation. Modern patent regimes emphasize international harmonization of substantive rules by reaching across borders for best practices and procedures. Scholars like Graeme B. Dinwoodie recognize the need for an international (or internationally minded) patent regime in today's global economy.[6] Peter K. Yu chronicles the changes in the American patent approach in light of the acceleration of globalization brought about by modern technology.[7] Yu notes that as the global economy transforms, the United States has become necessarily more aggressive in protecting its intellectual property internationally.[8] Nevertheless, to stay competitive in the global economy, the United States must not only protect the innovations of U.S. inventors, but also the innovations of foreign inventors.[9] It is also in the nation's best interests to help other countries adjust their intellectual property regimes to bring them into line with that of the United States.

The United States is not immune from this pressure to harmonize its patent system, which has prompted changes in its patent system as well. As an example, consider its recent move from a first-to-invent patent system to a modified first-to-file patent system.[10] Before 2011, a dispute concerning priority in the U.S. would be resolved in favor of the first inventor. Most

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4. THOMAS L. FRIEDMAN, THE WORLD IS FLAT 211 (2007).

5. *Id.* at 214.

6. *See generally* Graeme B. Dinwoodie, *Developing a Private International Intellectual Property Law: The Demise of Territoriality?*, 51 WM & MARY L. REV. 771 (2009) (calling for an improved private international property regime).

7. *See generally* Peter K. Yu, *From Pirates to Partners: Protecting Intellectual Property in China in the Twenty-First Century*, 50 AM. U.L. REV. 131 (2000).

8. *Id.*

9. *Id.*

10. John Villasenor, *March 16, 2013: The United States Transitions to a 'First-Inventor-To-File' Patent System*, FORBES TECH. BLOG (Mar. 11, 2013, 11:54 PM), http://www.forbes.com/sites/johnvillasenor/2013/03/11/march-16-2013-america-transitions-to-a-first-inventor-to-file-patent-system/.

other countries' patent systems determine priority based on which inventor was the first to file a patent application. With the passage of the America Invents Act ("AIA"), President Obama signed into law that crucial shift in the U.S. regime.[11] This change brings American patent law and patent procedures more in line with international approaches to patent law.[12]

Empirical work that studies the development and implications of the trends in international patenting is limited. Existing work is generally limited to statistical data compilation collected for government agencies or practitioners.[13] This Article presents an empirical study of Chinese patenting trends in the U.S. across several decades and uses three primary approaches to present a comparative analysis of these trends.

First, we compare current U.S. patenting trends from Chinese applicants to the patenting trends from other Asian countries and to the patenting trends from emerging BRICS economies (*i.e.*, Brazil, Russia, India, China and South Africa).[14] The results indicate that, between 2000 and 2012, the growth in U.S. patent applications from China greatly outpaced the growth in applications from Japan, South Korea, and the other emerging economies. Over this period, the technology mix (*e.g.*, chemical, biological, computers, mechanical) of Chinese patent applications in the U.S. weighted heavily toward communications and computing. There were similar results for patent applications originating from the other BRICS economies. Finally, from 2006 onwards, the allowance rate for Chinese applications began to converge with the allowance rate for Japanese and South Korean applications.

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11. *Id.*

12. Jessica C. Engler, *Chinese Patent Innovation and Competition Under the America Invents Act – A Whole New World of Prior Art*, LA. STATE UNIV. J. ENERGY L. & RESOURCES: ENERGY LAW CURRENTS (Mar. 28, 2013), http://sites.law.lsu.edu/jelrblog/2013/03/28/chinese-patent-innovation-and-competition-under-the-america-invents-act-a-whole-new-world-of-prior-art/. Organizations including the Intellectual Property Owners Association unsuccessfully urged the shift to a first-to-file jurisdiction on the basis of global harmonization for several years; the notion finally gained support and was included in the America Invents Act once justified on the basis of job creation. Wayne C. Jaeschke et al., *Comparison of Chinese and U.S. Patent Reform Legislation: Which, If Either, Got it Right?* 11 J. MARSHALL REV. INTELL. PROP. L. 567, 573 (2012).

13. For other studies in this area, *see e.g.,* WORLD INTELLECTUAL PROP. ORG., *2013 World Intellectual Property Indicator*, http://www.wipo.int/edocs/pubdocs/en/intproperty/941/wipo_pub_941_2013.pdf; BAKER & MCKENZIE, *Intellectual Property: Trends Around the World* (2012), *http*://www.bakermckenzie.com/files/Uploads/Documents/North%20America/IntellectualProperty/Baker%20&%20McKenzie_Doing%20Business%20Globally_10.9.12_Track%20V_Final.pdf.

14. WORLD INTELLECTUAL PROP. ORG., *supra* note 13, at 60. BRIC began as an acronym used to refer to Brazil, Russia, India and China as similar emerging economies. FORUM-BRICS, *About Us*, http://www.bricsforum.org/sample-page/ (last visited June 15, 2014) [https://web.archive.org/web/20150628120040/http://www.bricsforum.org/sample-page/]. Since that time, these countries have formed an international association in the same name, which was changed to BRICS when South Africa was included in 2010. *Id.*

This convergence indicates an increase in the quality of Chinese applications.

Second, we use historical data to compare the recent growth in Chinese patent applications filed in the U.S. to similarly active periods of growth for applications from South Korea and India during the late 20th century. We also use this data to consider the evolution of the technology mix and allowance rates in each case over these periods of intense growth in patenting activity. The rates of growth for the South Korean and Chinese patent applications in the U.S. are strikingly similar, and both are much higher than the growth rate of Indian applications. As these results show, the growth in applications from China is not unique historically, and Chinese patenting appears to be following a strategy that has already been successful for other large Far East Asian economies. In this sense, our work suggests that China is not an exception. Rather, it is just the latest emerging high-tech superpower following in the footsteps of Japan and South Korea. That said, current trends indicate that the increase of patent applications from Chinese inventors will continue for a longer period than similarly observed technological booms in countries like South Korea. International collaboration may contribute to the longevity of the Chinese patent boom. We observe that the percentage of foreign co-inventors on Chinese patent applications is much higher compared to South Korean patent applications from a comparable period.

Third, we examine data on the influx of foreign capital into China. These data show that Chinese patenting activities in the U.S. are spurred by foreign direct investments ("FDI") of multi-national corporations ("MNCs") in China. What may have started out as an effort by MNCs to seek low-cost manufacturing in China is now expanding to include more research and development ("R&D") activities. In fact, China appears to be increasingly separating itself from other BRICS countries in pursuing technology innovation and in seeking patent protection to bolster those R&D activities.

We explore trends in U.S. patenting by China and other BRICS nations by examining relevant theories for explaining those trends, by quantitatively analyzing those trends, and exploring their implications. Section I of this Article identifies current theories explaining the changing patent trends in China and proposes hypotheses to explain these changes and the implications thereof. The results suggest that Chinese technology is evolving at a far faster rate than in other developing economies, including those with the "triple convergence" advantage. In Section I, we also attempt to determine why China is experiencing patent growth at a rate much faster than other BRICS economies. Section II explains the study's methodology—including data selection and research methods—and the technology mix in patent applications and application allowance rates. Section III presents the results of the study, including patent applications, allowance rates, technology mix concentrations, and the percentage of foreign co-inventors for Chinese pat-

ent applications to the USPTO. Section III also analyzes the geographic distribution within China for Chinese patent applications and compares this to the geographic distribution for patent applications within other emerging and established economies. In Sections IV and V, we draw implications from our results and suggest how these data might augment further research.

I. HYPOTHESES

The underlying hypothesis of this Article is that a convergence of unique factors such as population size, growth rate, and political history makes China's recent innovation boom different from any other technological boom the world has experienced.[15] After adjusting for purchasing power, China overtook the United States as the world's biggest economy in 2014.[16] This economic growth coincides with rapid growth in the number of Chinese patent applications received by the USPTO. In light of this knowledge, we examine whether China followed a historical pattern of development in innovation or blazed an unprecedented trail. Other scholars, such as Yue Zhang, Peter J. Williamson and Ram Mudambi, have also looked at this increase and analyzed its implications.[17] This Section explores China's patenting trends in light of its increased investment in research and development by domestic and foreign entities, changes in the government's agenda and foreign policy, and increased exports of advanced technology products.

A. *Investment in Research and Development*

Many scholars point to the surge in Chinese R&D spending as a cause of increased innovation and the influx of patent applications.[18] The government and multinational corporations are both sources of this increased spending. For instance, Huawei Corporation, China's telecom giant, increased R&D spending by more than 25 percent in 2012.[19] Huawei holds more than 50,000 patents worldwide.[20] Another Chinese company, ZTE Corp, spent $1.4 billion on R&D in 2012.[21] ZTE led the world in number of Patent Cooperation Treaty filings in 2011 and again in 2012, with more than

15. *See infra* note 26.

16. Mike Bird, *China Just Overtook The US As The World's Largest Economy*, BUSINESS INSIDER, (Oct. 8, 2014, 5:08 AM), http://www.businessinsider.com/china-overtakes-us-as-worlds-largest-economy-2014-10; *China Set to Overtake U.S. as Biggest Economy in PPP Measure*, BLOOMBERG NEWS (Apr. 30, 2014, 3:32 PM), http://www.bloomberg.com/news/2014-04-30/china-set-to-overtake-u-s-as-biggest-economy-using-ppp-measure.html.

17. *See infra* notes 26, 33 & 35.

18. *See infra* notes 26 & 35.

19. Chris Neumeyer, *China's Great Leap Forward in Patents*, IP WATCHDOG, (Apr. 4, 2013, 10:30 AM), http://www.ipwatchdog.com/2013/04/04/chinas-great-leap-forward-in-patents/id=38625.

20. *Id.*

21. *Id.*

3,900 applications in 2012.[22] In total, China spends approximately $300 billion on R&D annually, second only to the United States in R&D expenditures.[23]

The efficiency of China's R&D spending in leading to patent applications provides further explanation for their exponential patent application growth. For every million dollars spent on R&D, Chinese companies apply for 3.5 patents.[24] American companies, by contrast, apply for 0.9 patents for every million dollars spent on R&D.[25] These patent application figures, however, raise more questions than they answer. For example, they do not address whether patents based on these applications will ultimately be issued or indicate the quality of those issued patents. The "efficiency" in generating patent applications might be linked to the Chinese practice of turning out innovative products faster and cheaper—but with less focus on quality—than their foreign counterparts.[26] If true, this would raise concerns about the quality of the patents.

Alternatively, Chinese patent generation efficiency may not indicate lower quality, but rather a different approach to patenting that focuses on incremental innovations. In Japan, for instance, it is a common practice to patent smaller improvements in the underlying technology than would be patented in the United States, where inventors often wait until the new invention's improvements over the old are clearer.[27] If Chinese companies are patenting incremental improvement, it may indicate a carefully considered evolution of a technology rather than a rushed product.

Determining the extent R&D spending drives Chinese patent growth is still a matter of debate among scholars. Professor Peter Yu contends that China will become a larger presence in the intellectual property market because of multinational firms' investment in China's R&D facilities.[28] It follows from this assertion that if multinational firms with a U.S. presence continue investing in China, Chinese patent applications in the USPTO will also continue to increase. Other studies, however, have focused on patents-R&D elasticity estimates and concluded that R&D spending "is unlikely to

22. *Id.*
23. *Id.*
24. *Id.*
25. *Id.*
26. Peter J. Williamson & Eden Yin, *Accelerated Innovation: The New Challenge from China*, MIT SLOAN MGMT. REV. (Apr. 23, 2014), http://sloanreview.mit.edu/article/accelerated-innovation-the-new-challenge-from-china/; *see also* DRUID, *Druid Debate on Innovative China*, VIMEO, 07:05-10:00 (June 23, 2014, 8:40 AM), http://vimeo.com/98925171 (comparing production timeline for Chinese iPhone equivalent).
27. Dan Rosen & Chikako Usui, *The Social Structure of Japanese Intellectual Property Law*, 13 UCLA PAC. BASIN L.J. 32, 42-44 (1994).
28. Peter K. Yu, *The Rise and Decline of the Intellectual Property Powers*, 34 CAMPBELL L. REV. 525, 552 (2012).

be the primary driving force of China's patenting boom."[29] Hu and Jefferson suggest that the accelerated restructuring of state-owned enterprises and increased privatization may be offer a better explanation for the upsurge of patenting in China.[30]

Nonetheless, multinational enterprises and foreign investors deserve at least partial credit for the Chinese patent boom. The growth of FDI prompted Chinese companies to file for more patent applications than they previously filed.[31] This increased international cooperation may contribute to Chinese companies' growing interest in protecting their intellectual property.[32]

B. *Government Agenda and Foreign Policy*

Another contributing factor to China's success is their government's intellectual property agenda. The State Council adopted their National Intellectual Property Strategy in June 2008, emphasizing the active development of intellectual property in China.[33] Government initiatives, like financial remuneration and tax breaks, reward Chinese inventors for filing patents both domestically and abroad.[34] One scholar, Ram Mudambi, cites the Chinese government's clear innovation plan and vision as factors that will set China apart as the world's leading innovative power by the year 2040.[35]

China's innovation policy was accompanied by aggressive patent law reform and, starting around 2008, the adoption of many practices similar to those of the USPTO.[36] China implemented additional regulations, including more detailed filing instructions, in 2010. These regulations are analogous to the U.S. rules of practice in patent cases, which include detailed directions that applicants and attorneys must follow in submitting applications.[37] China also enacted patent examination guidelines in February 2010 that are equivalent to the U.S. Manual of Patent Examination Procedure ("MPEP").[38] Part of the increase in Chinese patent applications before the USPTO may therefore be a side effect of these reforms. By making the SIPO application process more similar to the USPTO application process, China made its in-

29. Albert Guangzhou Hu & Gary H. Jefferson, *A Great Wall of Patents: What is Behind China's Recent Patent Explosion?*, 90 J. DEV. ECON. 57, 64 (2009).

30. *See id.* at 64-65.

31. *Id.* at 64.

32. *Id.*

33. Yu, *supra* note 28, at 530.

34. Neumeyer, *supra* note 19.

35. DRUID, *supra* note 26, at 28:47-41:07. For other arguments for and against the proposition that China will take over as the world's leading innovative power by 2040, watch the full debate.

36. Jaeschke et al., *supra* note 12, at 570.

37. *Id.*

38. *Id.*

ventors more knowledgeable and better equipped to apply for patents in the United States.

Several scholars assert that the influence of Western foreign policy led to the Chinese government's prioritization of intellectual property ("IP") rights. After decades of battling with the U.S. and other trade partners over lax enforcement of IP rights, it appears, at least with respect to patents, that external influences have helped push Chinese policy towards alignment with western IP systems.[39] When the owners of foreign patents forced the Chinese government to enforce their patent rights, domestic inventors began seeking the same rights, contributing to greater rates of patenting by Chinese nationals at home and abroad.

C. *Increase in Chinese Advanced Technology Products (ATPs) Exports*

Another explanation for the rapid increase in the number of patent applications from mainland China is an increase in patent-intensive advanced technology products ("ATPs"). An increasing share of Chinese exports to the U.S. are ATPs in sectors such as information and communication technology ("ICT") and optoelectronics (see Figure A6 in Appendix).[40] The Foreign Trade division of the U.S. Census Bureau defines ATPs as including products from high technology fields.[41] Because one ATP may contain several inventions, the production of ATPs is often considered a complex product industry. This is in contrast to discrete product industries, where the output sold to the end consumer stands alone and is not a combination of different products that may have been manufactured by someone else. When exporting a computer, for instance, a large number of patent owners will want the receiving country to enforce their rights. On the other hand, a

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39. Yu, *supra* note 7, at 136–54.

40. About 500 of some 22,000 commodity classification codes used in reporting U.S. merchandise trade are identified as "advanced technology" codes and they meet the following criteria:

- The code contains products whose technology is from a recognized high technology field (e.g.), biotechnology).
- These products represent leading edge technology in that field.
- Such products constitute a significant part of all items covered in the selected classification code.

This product and commodity-based measure of advanced technology differs from broader North American Industry Classification System (NAICS) industry-based measures, which include all goods produced by a particular industry group, regardless of the level of technology embodied in the goods. The Foreign Trade Division of the U.S. Census Bureau assigns ATP classifications. For the full list of classification codes, *see Foreign Trade*, U.S. CENSUS BUREAU, http://www.census.gov/foreign-trade/reference/codes/#atp (last visited Nov. 6, 2014). *See also* Alexander Hammer, Robert Koopman & Andrew Martinez, *Overview of U.S.-China Trade in Advanced Technology Products*, 3 J. INT'L COMM. & ECON. 1, 7–8 (2011) (describing the increase in Chinese exports of APTs to the U.S.).

41. Common Trade Definitions, U.S. Census Bureau, *https://www.census.gov/foreign-trade/reference/definitions/index.html* (last visited Oct. 2, 2015).

pharmaceutical export would likely only concern a single entity and a single patent owner. The share of ATP exports (*i.e.,* involving complex product industries) from China increased from 16 percent in 2002 to 33 percent in 2012.[42] Meanwhile, the ATP share of total exports to the U.S. fell for the other BRICS, although the bulk of this decline occurred in Brazil and Russia (see Figure A6 in Appendix). Some point out that a large number of these exports are merely processed in China, and therefore may not implicate innovations by Chinese inventors; but non-processing exports have also increased. In fact, China's share of high and medium-high technology exports grew by over 20 percent between 1997 and 2007.[43]

Chinese industry has shifted from discrete product industries toward complex product industries.[44] Operating in these complex industries brings far greater incentives to patent, both to protect one's own innovative products and to equip one's firm with a complex patent portfolio for negotiation purposes.[45] Increased R&D and an influx of foreign capital contribute to the growth of complex industries and to the increase in patent applications, as discussed above. A more educated population also provides additional human capital to support R&D efforts.[46] Demand-side drivers may cause an increase in complex product industries that address specific challenges, like pollution and high population density.[47]

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42. The data used to generate the graph in Figure A6 can be found at *Advanced Technology Product Data – Imports and Exports, ATP Group by Country*, U.S. CENSUS BUREAU, http://www.census.gov/foreign-trade/statistics/product/atp/select-atpctry.html (last visited Nov. 30, 2015).

43. DRUID, *supra* note 26, at 39:00-40:00.

44. Javade Chaudhri, *Chinese Industrial Policies: Indigenous Innovation, Intellectual Property Rights, and the Trade Issues of the Next Decade*, 34 T. JEFFERSON L. REV. 1, 4-5 (2011).

45. Hu & Jefferson, *supra* note 29, at 58. Complex product industry actors tend to produce three times as many patent applications as discrete product industries. *Id.* at 61.

46. Riccardo Crescenzi et al., *The Territorial Dynamics of Innovation in China and India*, 12 J. ECON. GEOGRAPHY 1055, 1058 (2012) ("Both India and, in particular, China have invested heavily in innovation 'inputs.' Both countries have witnessed rapidly rising literacy rates and education enrollment . . . Moreover, the rise in university placement in the two countries has been absolutely phenomenal."). *See e.g.*, Anil K. Gupta & Haiyan Wang, *China as Innovator, Not Just an Imitator*, BUS. WEEK (Mar. 9, 2009, 7:41 AM), http://www.businessweek.com/stories/2009-03-09/china-as-an-innovator-not-just-an-imitatorbusinessweek-business-news-stock-market-and-financial-advice ("Many of the scientific leaders who are overseeing the utilization of [government R&D] funds are highly qualified Western-educated researchers returning to China in growing numbers.").

47. Gupta & Wang, *supra* note 46 ("The social and economic challenges that are either unique or particularly acute in China are likely to serve as the demand-side derivers of innovation."). As an example Gupta & Wang offer BYD, a Chinese based company that became the world's first company to start selling a plug-in electric hybrid car. *Id.*

II. Data and Methods

To evaluate our hypotheses that foreign investment, government policy, or shifts in the types of technologies might be the driving factors behind Chinese patent growth, we examined the USPTO data on these patents. Specifically, we evaluated the number of patent applications originating from China, allowance rates for those applications, and the mix of technologies covered by these patent applications. We also compared Chinese patenting activity with the patenting activity of inventors in other countries. Because examination standards differ across patent offices, comparing domestic filings in China with domestic filings in other countries may lead to spurious findings. By focusing on USPTO filings, we are able to control for examination standards.

The number of applications received may help decipher whether China's current patenting trends are unique or are following the development pattern observed in other Far East Asian countries in the past. Comparing patent applications from China to those from other countries shows how China's patent activity is different from that of other emerging and established economies. This may also be helpful in understanding whether the influx of R&D in China has been effective and efficient, and whether it may be used to project future patenting behavior.

Allowance rates and the change in allowance rates are helpful in determining whether the increase in applications is merely the result of a push for more applications or whether the development of patentable technology in China is increasing in real terms. Allowance rate data may also be helpful in establishing the impact of MNCs and U.S. and Chinese policies on the quality of patent applications.

The technology mix of applications may back up the assertion that the Chinese innovation market is becoming more advanced, which would in turn explain the increase in patent applications. Examination of the concentration in the technology mix among patent applications may have implications for whether China's patent trends are sustainable or just the result of a single-industry boom.

To understand whether China is exhibiting unique trends or following historical patterns, we first compare Chinese patent trends between 2000 and 2012 with those trends from the other BRICS countries and with Japan and South Korea during the same period. We then make a historical comparison using South Korea and India as benchmarks. In our analysis, we compare China's highest ten-year growth in patent applications period, 1997-2007, with similar high-growth rate periods experienced by the comparison groups, such as South Korea, India and the BRICS countries. We chose the South Korean comparison group because the growth in the number of South Korea applications between 1986 and 1996 was similar to the growth in Chinese applications from 1997 to 2007. We chose the Indian comparison

group because the growth in applications from that country has greatly exceeded the growth in applications from the other major emerging economies outside of China. These two sets of data (comparing China, BRICS, and Japan/South Korea between 2000 and 2012 and comparing China, South Korea, and India during their respective high-growth periods) are examined for each observed trend. Moreover, virtually all the patent applications in our dataset from pre-2007 have proceeded to a final disposition.

A. *Measuring the Increase in Patent Applications*

The data used to calculate patent application statistics in this study are from the USPTO's internal Patent Application Location and Monitoring ("PALM") system. Patent examiners at the USPTO use the PALM system to monitor the progress of prosecution of each patent application. The PALM data include the following information: (1) the date that each application was received by the USPTO; (2) the identities of the inventors; (3) the addresses of the inventors; (4) the art unit to which the application is assigned; and (5) the ultimate disposal state (allowed, abandoned, or pending) of the application. All patent applications received by the USPTO, including those that have never been published, are present in PALM.[48] The analyses that follow consider only regular utility patent applications, not design patent applications or provisional patent applications.

We define an application's country of origin as the country of residence of the application's first-named inventor. The Chinese applications included in the study do not include applications where the first-named inventor was from Hong Kong, Macau, or Taiwan. The applications can, however, include cases where a foreign national, who is living in China, is the first-named inventor. Chinese applications also include many cases in which Chinese nationals, living in China but working for multinational enterprises, are first-named inventors.[49] A similar approach is used to determine which applications originated from each of the comparison countries.

B. *Measuring Patent Allowance Rates*

Our calculated allowance rates come from the set of all applications that had either been abandoned or allowed as of August 2013. The allowance

48. In this way, PALM differs from the public version of the Patent Application Information Retrieval (PAIR) system. Public PAIR only includes applications that have been made public due to the issuing of a patent, the publication of the application, or for other reasons. The PALM data can only be accessed by PTO personnel who can show reason for needing to access it. *See* USPTO, Application Records and Reports (2015), http://www.uspto.gov/web/offices/pac/mpep/s1704.html.

49. Analysis of patent assignment data reveals that a significant portion of U.S. patents applied for by inventors from China and India are owned by multinational corporations. Based on our analysis of the PALM data, we find that more than half of the U.S. applications from Chinese first-named inventors include co-inventors. Roughly, 20 percent of these include co-inventors that do not reside in China (data on file with author).

rates are reported for the year of application rather than the year of disposal. As an example, consider a case where the USPTO received 10,000 applications from inventors in a given country in 2006. Suppose that by August 2013, 4,500 of the applications had been issued as a patent, 4,500 had been abandoned, and 1,000 were still pending. The allowance rate for 2006 would be 50 percent (*i.e.,* 4,500 total issued patents divided by 9,000 total disposals).

We also address two issues regarding the allowance rate results. First, the allowance rates we calculate are only for applications that have been disposed, even though many of the applications filed in the later years are still pending. It is unclear what the final allowance rate will be for applications filed in these years. However, for applications filed in the earliest years (2000 through 2002), we found no evidence that the final allowance rate differed from the allowance rates for the first 20 percent of applications disposed from each of those years. In essence, the allowance rate for disposed applications when only 20 or 30 percent of the applications have been disposed appears to be a good estimate of what the final allowance rate will be after all applications have been disposed. Thus, we are confident that the convergence of allowance rates in the later years is not due to biased measures of the final allowance rates.

Second, the allowance rates we calculate from different countries may vary based primarily on the different technology mixes of the applications from those countries. Some technology areas, such as biotechnology, exhibit lower allowance rates. Thus, overall allowance rates may change simply due to changes in the technology mix. We used multivariate statistical models to control for the differences in the technology mix,[50] and the result regarding the convergence of the Chinese allowance rate to the Japanese/South Korean allowance rate did not change. After controlling for technology mix, we found that the allowance rate for the other major emerging economies also converges toward that of Japan and South Korea. However, the rate of convergence is still greater for the Chinese patent applications.

C. *Measuring the Technology Mix*

To examine the technology mix of incoming applications, we consider the technology centers ("TCs") at the USPTO to which they are assigned. We group the technology centers into the following six technology categories based on the USPTO's technology center categories:

50. We used a logistic regression model and included dummies for country and technology, along with their interactions. We performed a logistic regression on all patent applications from China and the comparison groups to adjust the allowance rates. The regression included the indicators for technology area, year of application, China applications, BRIC applications, interactions between China and year of application, and the BRIC country and year of application. We then used the odds ratios from this logit model to adjust the Chinese and BRIC allowance rates vis-à-vis the Japan/Korea allowance rates.

- Biotechnology and organic chemistry (BIO) – TC 1600[51]
- Chemical and materials engineering (CHEM) – TC 1700[52]
- Computers and communications (COMP)[53] – TCs 2100, 2400, and 2600[54]
- Semiconductors, electrical and optical systems and components (SEMI) – TC 2800[55]
- Transportation, construction, electronic commerce, agriculture, national security and license & review (TRANS) – TC 3600[56]
- Mechanical engineering, manufacturing, products (MECH) – TC 3700[57]

While examining the changes in the technology mix, we also consider changes in the relative concentration of the technology mix over time for each country (or group of countries) of interest. To do so, we used the Herfindahl-Hirschman Index ("HHI"), a measure commonly used by economists when examining market concentration. To calculate the index, we first calculate the share of all applications in each of the six technology areas. We then square each of these shares and sum them up. Higher values of the index indicate higher levels of concentration. Given that we have six technology areas, the smallest value the index can take on is 0.167, which would indicate a uniform distribution of applications across the six technology ar-

51. In prior years, TCs 1200 and 1800 (no longer in use) mapped to the BIO area. John L. King, *Patent Examination Procedures and Patent Quality*, *in* PATENTS IN THE KNOWLEDGE-BASED ECONOMY 54, 58 (Wesley M. Cohen & Stephen A. Merrill eds., 2003).

52. In prior years, TCs 1100, 1300, and 1500 (all no longer in use) mapped to the CHEM area. *Id.*

53. In the areas of computers and telecommunications, the TCs have not been stable since 2000. Currently these types of patent applications are assigned to one of the following three TCs:

- 2100 – Computer Architecture, Software, and Information Security
- 2400 – Computer Networks, Multiplex Communication, Video Distribution and Security
- 2600 – Communications

TC 2400 is relatively new; applications that would commonly be assigned to that TC would have been assigned to either 2100 or 2600 earlier in the decade. Thus, we decided to combine these three TCs into one category called "computers and communications." USPTO, OFFICE OF THE DEPUTY COMMISSIONER FOR PATENT OPERATIONS, http://www.uspto.gov/about-us/organizational-offices/office-commissioner-patents/office-deputy-commissioner-patent.

54. In prior years, TCs 2300 and 2700 (both no longer in use) mapped to the COMP area. King, *supra* note 51, at 58; *see also* USPTO, CONSUMER SATISFACTION SURVEY FOR APPLICANTS, http://www.uspto.gov/web/offices/com/oqm-old/asci_survey.pdf.

55. In prior years TCs 2200 and 2500 (both no longer in use) mapped to the SEMI area. Prior to 1998, TC 2100 mapped to the SEMI area instead of the COMP area. King, *supra* note 51, at 58.

56. In prior years TCs 3100 and 3500 (both no longer in use) mapped to the TRANS area. *Id.*

57. In prior years TCs 3200, 3300, and 3400 (all no longer in use) mapped to the MECH area. *Id.*

eas. The largest value that the index can take on is 1, which would indicate that all of the applications were assigned to just one of the six technology areas.

D. *Calculating Geographic Concentration and Foreign Co-invention*

We used the location information from the PALM database to analyze the degree of geographic concentration for patent applications filed in the U.S. from China. We identify several regions in China that are particularly productive in patent applications. Again, we employ the HHI, explained above, in calculating the relative geographic concentration of patent applications for different regions in China.

We also determined the percentage of U.S. patent applications from China that had at least one foreign co-inventor but with first-named Chinese inventors for the period from 2000 to 2011. We then obtained similar foreign co-invention data for U.S. patent applications originating from Japan; South Korea; United States; the European Union including Switzerland; "Other China," which includes Taiwan, Hong Kong, and Macao; and "Other East Asia," which includes the ASEAN countries and Mongolia.

III. Results and Analysis

The results of our study are organized by the four patent trend measures that we focused on: patent applications, allowance rates, concentration in technology mix, and geographic concentration. For each trend, the results from the first data set (focusing on the current time period and on applications from China, the BRICS countries, and Japan or South Korea) are discussed first, and the results from the second set (focusing on the respective ten-year high-growth periods for China, South Korea, and India) are discussed second.

A. *The Divergence of China's Innovation Economy from Other BRICS Nations*

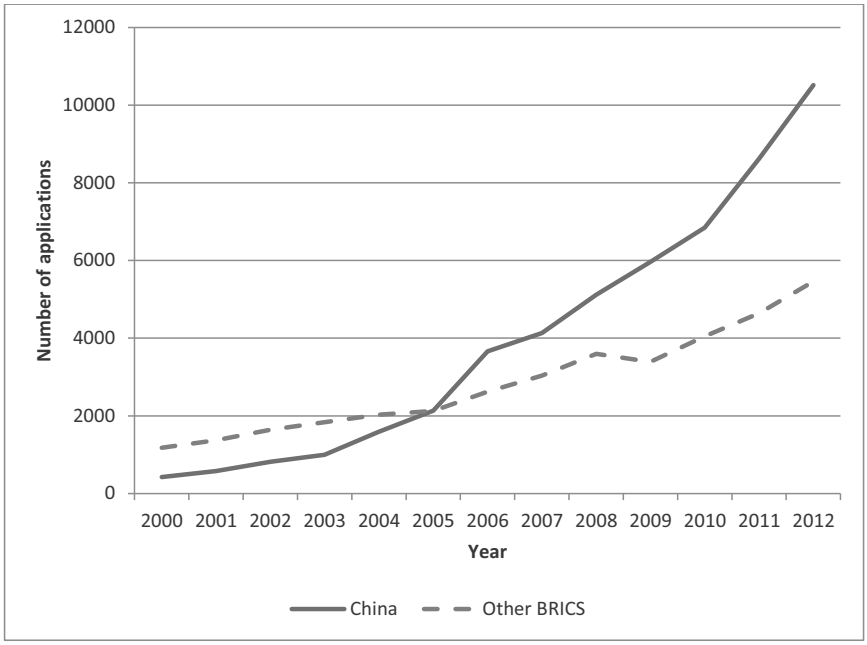
Since 2000, China has distinguished itself from other BRICS nations in its approach to patenting. Our results show that China has seen an increase in patent applications in addition to higher allowance rates. China has also emphasized rapidly developing technological areas like computing and semiconductors where new products often require a large number of innovations.

1. Patent Applications to the USPTO: 2000-Present

The increase in USPTO patent applications from Mainland China since 2000 has outpaced applications from the other BRICS economies, as shown in Figure 1. The USPTO received 422 patent applications from Mainland China in 2000, as compared to 1,200 applications from the other four BRICS

countries.[58] By 2006, the USPTO was annually receiving 40 percent more applications from China than from the other four emerging economies combined. In 2012, the number of applications from China was more than 90 percent higher than the number of applications from the other emerging economies. This is in part due to the tax incentives given to American companies in China, leading to an intensification of R&D in China and prompting Chinese firms to file for more patent applications at home and abroad.[59]

FIGURE 1. GROWTH IN THE NUMBER OF UTILITY PATENT APPLICATIONS TO THE USPTO FROM CHINA AND OTHER BRICS ECONOMIES, 2000-2012



Even with the growth in Chinese patent applications, the number of applications from China was still quite small over this period when compared to the number of applications coming from Japan and South Korea.[60] Japanese and South Korean inventors accounted for roughly 50,000 applications in the year 2000, with applications from these two countries peaking at a little over 80,000 in 2007. The number of applications from Japan and South Korea fell slightly following the financial crisis in 2008, but rebounded to 79,000 by 2012. This growth in the number of applications since

58. If current trends continue, the number of Chinese patents granted by the PTO will exceed the number of patents from Germany, Britain, Italy, and France combined by the year 2020. Gupta & Wang, *supra* note 46.

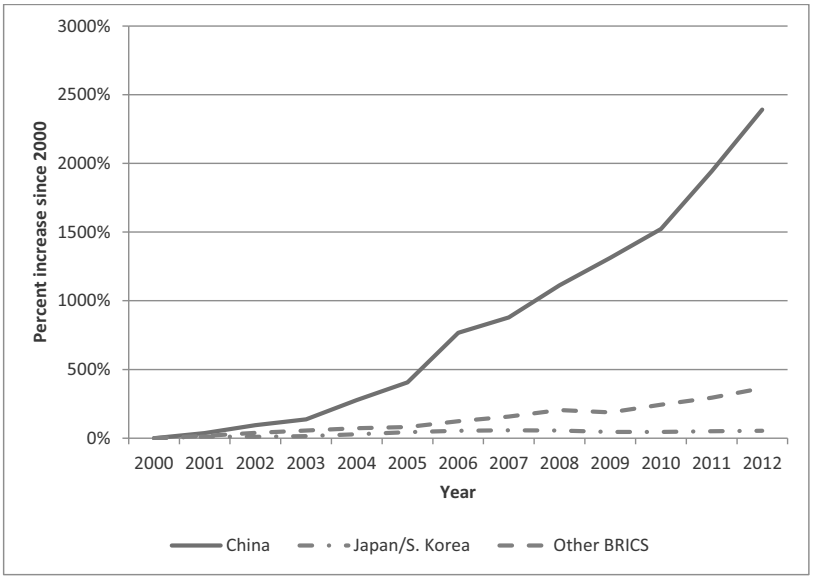
59. *See* Hu & Jefferson, *supra* note 29, at 64.

60. This explains why the numbers for U.S. patent applications from Japan and Korea are not included in Figure 1.

2000 is comparable to the growth in the number of patent applications from U.S.-based inventors during the same period – increasing at an average annual growth rate of 3.7 percent. Within the same period, however, growth in patent applications from U.S.-based inventors was much lower than growth in the number of foreign applications to the USPTO, which roughly doubled over the same twelve-year period reflecting an average annual growth rate of 6 percent.

While the absolute numbers of patent applications from China were not as high as those from other East Asian countries, the growth rate of Chinese patent applications far exceeded that of other foreign applications. In Figure 2, we compare China's rate of growth in patent applications with those of the two comparison groups (Japan/South Korea, and the other BRICS). The number of applications from the other BRICS grew at an average annual rate of roughly 11 percent, so that by 2012, the USPTO received more than three times as many applications from these countries than it had received from them in 2000. Thus, the number of applications from these countries grew at a rate far greater than that of all foreign applications. Over this same period, however, the number of applications from Mainland China grew at an average annual rate of 31 percent. This means that by 2012, the USPTO was receiving 25 times as many applications from Chinese inventors as it had received in 2000.[61]

FIGURE 2. COMPARING THE RATE OF GROWTH OF USPTO UTILITY PATENT APPLICATIONS FROM CHINA TO THE COMPARISON GROUPS, 2000-2012

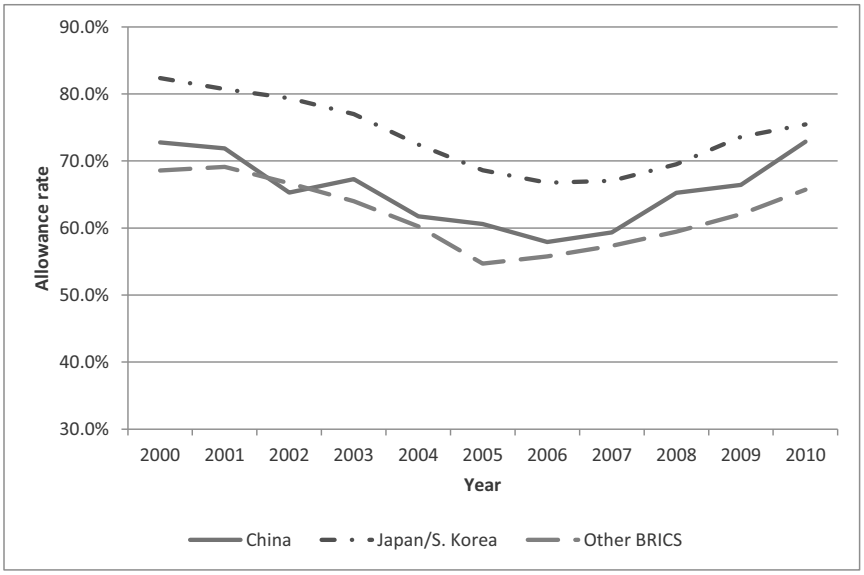


61. Interestingly, this growth rate is very similar to the rate of growth in patent applications to SIPO from Chinese residents. *See* WORLD INTELLECTUAL PROP. ORG., *supra* note 1.

2. Allowance Rates for Applications to the USPTO: 2000-Present

The enormous increase in the number of patent applications from China did not decrease the quality of the patent application as measured by patent allowance rates. Figure 3 illustrates how the allowance rates have changed for Chinese applications as well as for the two comparison groups: Japan/ South Korea, and the other BRICS economies. Among the three groups discussed here, allowance rates have been highest for applications from Japan and South Korea. For applications received from these two countries in 2000, the allowance rate was slightly over 80 percent (as compared to roughly 66 percent for applications from China and the other major emerging economies). Allowance rates generally fell, regardless of origin, through 2007, but have been increasing since that time. As shown in Figure 3, the allowance rate for Chinese applications in the USPTO has been steadily converging with the allowance rate for Japanese and South Korean applications. At the same time, it has been diverging from the relatively lower allowance rates of the other BRICS countries where China found itself in the earlier years shown in Figure 3. This improvement in allowance rate may indicate that Chinese applicants are adapting to the system in use by the USPTO. The allowance rate also may have been improved by increased international cooperation with inventors who were already familiar with USPTO practices and regulations.

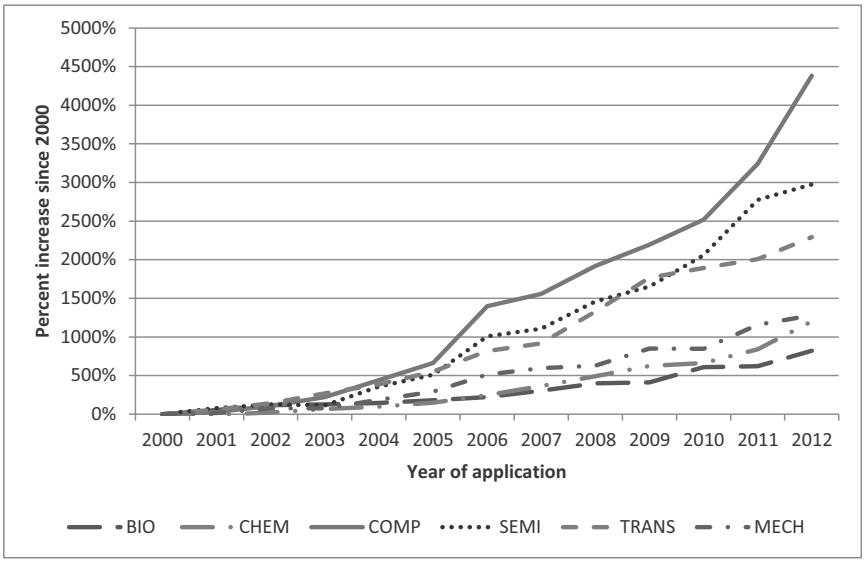
FIGURE 3. COMPARING ALLOWANCE RATES OF DISPOSED APPLICATIONS, 2000-2010



3. Evolution of the Technology Mix for Applications to the USPTO: 2000-Present

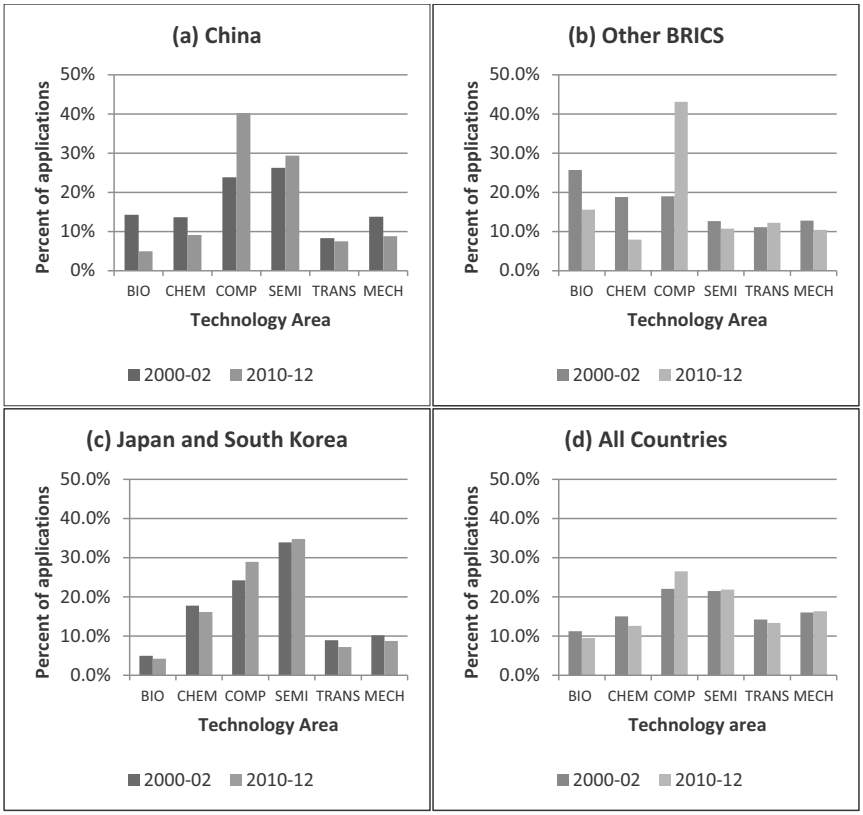
The growth rate of the number of applications from China has not been uniform across technology areas, as illustrated in Figure 4. The highest rates of growth have come in computers and communications (COMP) and in electrical engineering and optics (SEMI). In each of these areas, the numbers of applications have grown at average annual rates of 37 percent and 33 percent, respectively. The biotechnology area has experienced the lowest growth at an average annual rate of 19 percent.

FIGURE 4. THE GROWTH OF USPTO UTILITY PATENT APPLICATIONS FROM CHINA BY TECHNOLOGY AREA, 2000-2012



Comparing the technology mix of 2000 to 2002 with that of 2010 to 2012, we note that Chinese patent applications have shifted from the biotechnology, chemical and mechanical areas to computer and semiconductor. Panel (a) in Figure 5 illustrates this change in the technology mix of Chinese patent applications. Given the results presented in Figure 4, it is not surprising to see a shift away from the technology areas that have been growing least quickly (BIO, CHEM, and MECH) to the two fastest growing technology areas (COMP and SEMI). The change in the share of all applications assigned to COMP has grown much larger, from 24 percent at the beginning of the period to 40 percent at the end of the period. Panels (b) through (d) in Figure 5 show the changes in the technology mixes for three different comparison groups. Panel (b) shows the changes for the other BRICS economies; Panel (c) shows the changes for Japan and South Korea; and Panel (d) shows the changes for all applications to the USPTO for the same period.

FIGURE 5. CHANGE IN TECHNOLOGY MIX, APPLICATIONS TO THE USPTO FROM VARIOUS COUNTRIES, 2000-02 TO 2010-12



Similar to the Chinese patent application technology mix, the technology mix for the other BRICS economies has skewed more toward COMP and away from the BIO, CHEM, and MECH areas. The share of all applications from these countries assigned to COMP has more than doubled over the past decade.

The share of applications from Japan and South Korea assigned to COMP has grown, but less so than for either China or the other BRICS countries (see Figure 5 and Figure A1 in Appendix). From 2000 to 2002, 24 percent of the applications from Japan and South Korea were in COMP. By the later time-period—2010 to 2012—the share of COMP applications had grown to 29 percent, though SEMI continued to receive the greatest share of applications, with a 34 percent share at the beginning of the period and a 35 percent share at the end of the period. The growth in the shares of the COMP and SEMI areas was offset by small decreases in the shares of the other technology areas.

The relative stability of the technology mix for Japan and South Korea is likely a result of a greater level of maturity in those countries' economies. As a final comparison, Panel (d) of Figure 5 presents the change in the technology mix of all patent applications received by the USPTO. Again, the shares of applications in COMP and SEMI are seeing small increases, but the result is not nearly as pronounced as the results are for China and the other major emerging economies. The rush to attempt patenting innovations in the COMP area by inventors in these emerging economies, including China, does not appear to be a broader trend encompassing other technology areas. For China and the other BRICS economies, there has been a much greater shift into the COMP and SEMI technology areas and away from the other technology areas.[62]

The technology mix of Chinese applications has not only changed significantly over the past decade, but that it has become more concentrated (see Figure 6). In 2000, China's technology mix was not concentrated in any one or two areas, with an HHI of 0.18. The same could be said for the technology mix for the other BRICS, with an HHI of 0.17. By 2006, however, the technology mix of Chinese applications had become much more concentrated (skewed toward the COMP and SEMI areas), and the HHI had increased to 0.27 by 2006. The technology mix of Chinese applications has subsequently flattened and maintained a comparable level of concentration from 2006 to 2012. The involvement of multinational corporations in the electrical and electronics/computer industry helps explain why the SEMI area has become so concentrated. Since 2006, a sudden increase in new Class 361 (the USPTO's designation for electrical system and device patents) patents from China can be traced to R&D that is heavily focused on China's electrical and electronics industry.[63] For example, Foxconn Technology Co. is responsible for 90 percent of China's newly issued American patents in the USPC 361 sector.[64] Foxconn is a Taiwanese multinational company with major American clients, including Amazon, Apple, Microsoft, and Dell.[65] Foxconn is also planning on expanding its American manufacturing power with new factories in the U.S.[66] It is unsurprising that a multinational corporation with significant American involvement would be adept at prosecuting patent applications at the USPTO.

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62. *See* Appendix, Figure A1.

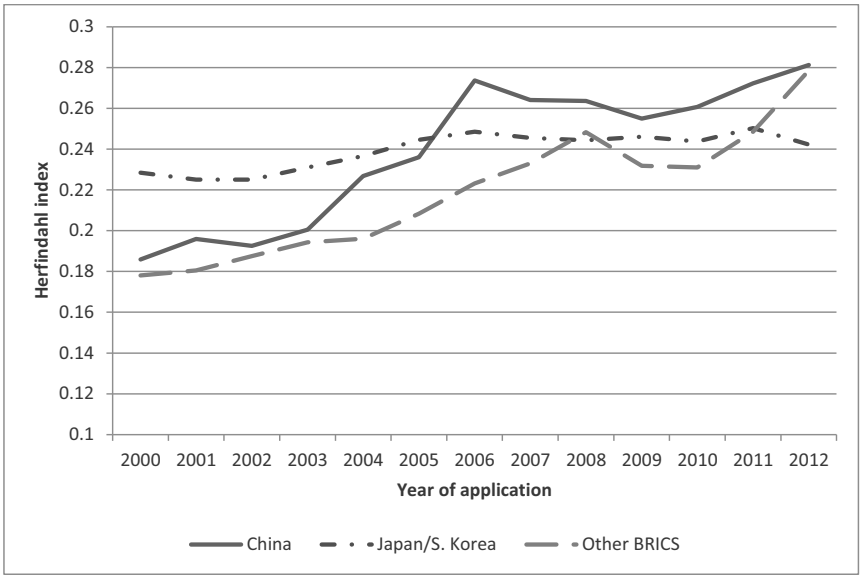
63. Jia Zheng et al., *Industry Evolution and Key Technologies in China Based on Patent Analysis*, 87 SCIENTOMETRICS 175, 183 (2010).

64. *Id.* at 182.

65. Charlie Osborne, *Foxconn in Talks to Boost Manufacturing in United States*, ZDNET (Jan. 24, 2014, 10:40 AM), http://www.zdnet.com/foxconn-in-talks-to-boost-manufacturing-in-united-states-7000025724/.

66. *Id.*

FIGURE 6. TECHNOLOGY MIX CONCENTRATIONS OF APPLICATIONS FROM CHINA, JAPAN, AND SOUTH KOREA, AND OTHER BRICS ECONOMIES, 2000-2012



The technology concentration of applications from the other BRICS has also increased, although this increase was not pronounced until 2012 (see Figure 6). The HHI for these countries had increased from 0.17 in 2000 to 0.25 by 2008. The HHI for these emerging economies stayed between 0.23 to 0.25 before increasing sharply to 0.28 in 2012. The technology mix concentration of Japanese and South Korean applications was high relative to those of the other comparison groups for the first part of that period, but has also remained fairly consistent, rising only slightly from 0.235 to 0.25 over that period. Since 2006, the technology concentration for Japan and South Korea has been lower than China's and similar to that of the other BRICS countries.

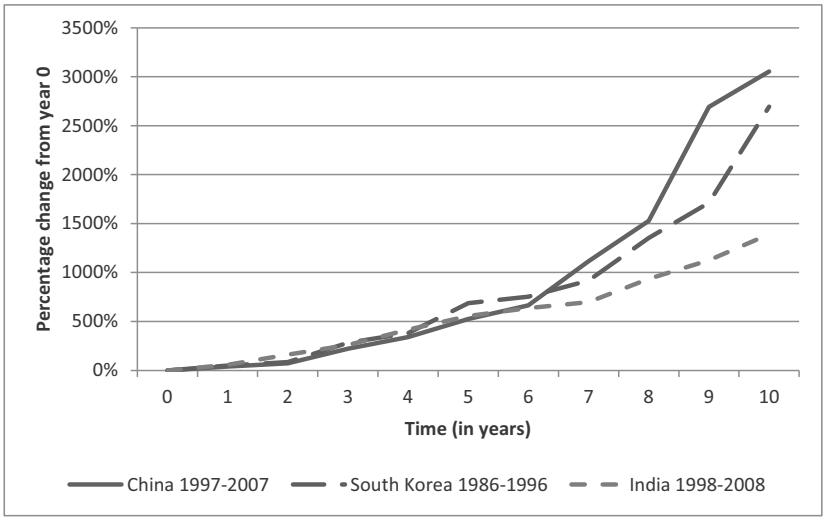
B. *China's Development Boom Mirrors Other East Asian Countries*

Our empirical results demonstrate that as China's patenting trends diverged from those of the BRICS nations and other emerging economies, they became more similar to patenting trends observed in South Korea and India during their high-growth periods. The shift in technology mix that accompanied each country's technology boom provides additional insights (*e.g.,* the technology sectors that drove the boom) into the big picture of innovation and patent protection.

1. Patent Applications to the USPTO: High-Growth Periods

In India, South Korea, and China, the number of applications in the base year is quite small at the beginning of the high-growth period. This number ranged from 131 applications from China in 1996 to 158 applications from South Korea in 1986 to 164 applications from India in 1998. Figure 7 illustrates how quickly the number of applications from each of these countries grew over the following ten years. The growth in Chinese applications from 1996 to 2006 was remarkably similar to the growth in South Korean applications over the previous decade (1986 to 1996), especially through the first eight years (through 2005 in the case of China). In each case, the number of applications at the end of the period was roughly 30 times higher, which reflected a roughly 40 percent average annual growth rate over ten years. Even India, with its 30 percent average annual growth rate in applications from 1998 to 2008, is left lagging.[67] This comparison shows that the recent explosive growth in applications from China has at least one precedent.[68]

FIGURE 7. GROWTH IN UTILITY PATENT APPLICATIONS TO THE USPTO FROM CHINA (1997-2007), SOUTH KOREA (1986-1996), AND INDIA (1998-2008)



Source: Authors' calculations based on PALM data collected by the USPTO

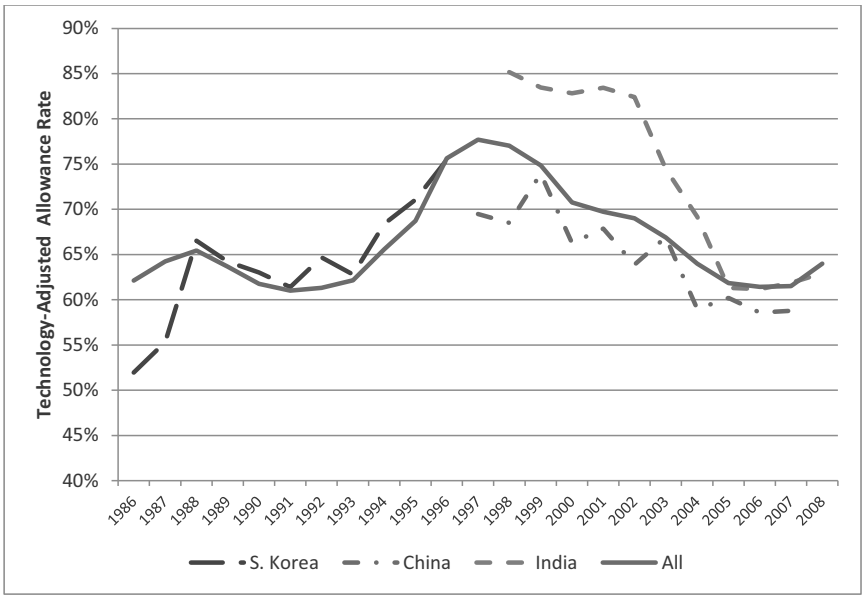
67. Why else might India be left lagging? One critic argues that the geography of innovation in China and India is different. In China, agglomeration forces, linked to population, industrial specializations, and infrastructure endowment, drive innovation. In India, innovation is more dependent on a combination of good local socioeconomic structures and investment in science and technology. *See generally* Crescenzi et al., *supra* note 46.

68. China has also been, and is predicted to continue to be, successful in securing patents. If trends continue, by 2020, the number of China-originated granted patents will exceed the number of granted patents from Germany, Britain, France and Italy combined. Gupta & Wang, *supra* note 46.

2. Allowance Rates for Applications to the USPTO: High-Growth Periods

When adjusted by technology area,[69] the allowance rate for South Korean applications generally increased while the allowance rates for Chinese and Indian applications generally decreased over the periods of interest (see Figure 8). It appears, however, that these trends were driven by general trends in the overall allowance rate for all patent applications in the USPTO. If anything, the evolution of South Korean and Chinese allowance rates followed the evolution of the allowance rates for all applications to the USPTO. The decrease in the allowance rate for Indian applications was more dramatic than the underlying decrease in the allowance rate for all applications to the USPTO. Additionally, the technology area-adjusted allowance rate for South Korean applications from 1988 through 1996 was generally on par with the overall allowance rate at the USPTO, while the allowance rate for Chinese applications from 1997 through 2007 was generally lower than the overall allowance rate, with a recent reduction in the gap by 2012 (see Figure 8). The allowance rate for Indian applications went from being much higher than average from 1998 to 2002 to being average by 2005.

FIGURE 8. COMPARING THE TECHNOLOGY-ADJUSTED ALLOWANCE RATES FOR SOUTH KOREA (1986-1996), CHINA (1997-2007), AND INDIA (1998-2008)



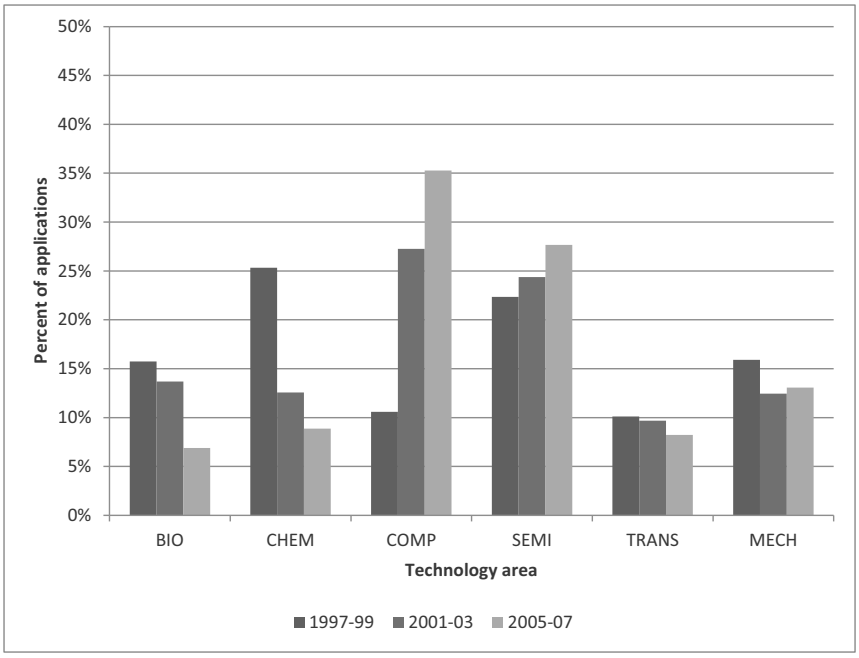
Source: Authors' calculations based on PALM data from the USPTO.

69. *See supra* Section III.B.

3. Evolution of the Technology Mix for Applications to the USPTO: High-Growth Periods

For each high-growth period case, we analyze the evolution of the technology mix for applications received from the country over the ten-year period. Figure 9 illustrates how the technology mix changed for Chinese applications. At the beginning of the period (1997 to 1999), the CHEM and SEMI technology areas were most important, accounting for 25 percent and 22 percent of all applications, respectively (see Figure 9). By the end of the period, the CHEM area accounted for only 9 percent of all applications, while the COMP area had grown from a 10 percent share to a 35 percent share. The BIO area had also become a smaller share of applications, falling from 15 percent to 7 percent over the same period.

FIGURE 9. CHANGE IN TECHNOLOGY MIX, CHINESE APPLICATIONS TO THE USPTO, 1996-2006

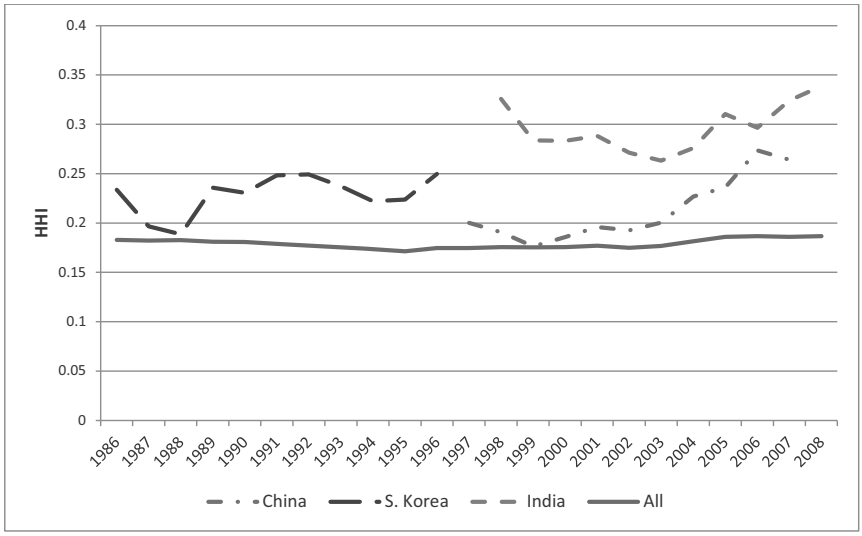


By comparison, applications from India in the late 1990s were heavily concentrated in the BIO area (see Figure A2 in Appendix). Roughly 45 percent of the applications were in that area. By the end of that period, the Indian applications were still heavily concentrated in one area, but that area had switched from BIO to COMP. For the 2006 to 2008 period, the COMP technology area accounted for roughly half of all applications. During South Korea's ten-year high-growth period, the share of all applications in the SEMI area grew from 20 percent to 35 percent (see Figure A3 in Appendix).

During this same period, the shares of applications in the TRANS and MECH areas each fell by at least 30 percent.

In each high-growth case, the technology mix concentration rose steadily after an initial drop. This can be seen in figure 10, which compares the technology mix of China, South Korea, and India to the overall technology mix at the USPTO at the time.[70] For China, the HHI initially fell from 0.2 to 0.175 between 1997 and 1999, but then rose to 0.275 by 2006. For South Korea, the HHI initially fell from 0.24 to 0.19 between 1986 and 1988, but then rose to 0.25 by 1992 and fluctuated between 0.22 and 0.25 through 1996. The technology mix concentration was generally much higher for India. The HHI initially fell from 0.33 in 1998 to 0.26 in 2003, only to rise again to 0.34 by 2008. It is also worth noting that the technology mix of applications from China was generally the least concentrated of the technology mixes during the country's periods of fast growth, except toward the end of the ten-year period where China's technology mix concentration for 2006 and 2007 was slightly higher than the concentration for South Korea for 1995 and 1996.

FIGURE 10. CHANGE OF THE CONCENTRATION OF THE TECHNOLOGY MIX FOR APPLICATIONS FROM THE THREE COUNTRIES AND FOR ALL APPLICATIONS (HHI MEASURE)

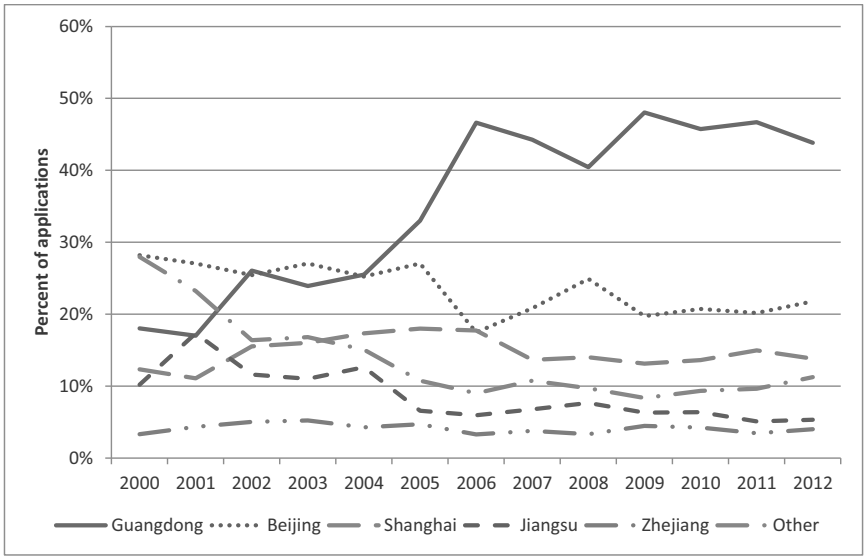


70. We again use the HHI to measure the technology mix concentration. *Supra* Section III.

C. *Geographic Concentration in China*

As the technology mix of Chinese applications to USPTO has become more concentrated, so has the geographic mix of patent applications from regions in China. Figure 11 illustrates how the mix of applications evolved between 2000 and 2012. The results focus on the following regions in China: Guangdong province, Beijing municipality, Shanghai municipality, Jiangsu province, Zhejiang province, and other regions. At the beginning of the millennium, more applications came from Beijing municipality (28 percent) than from any other region. At that same time, slightly less than 20 percent of the applications came from the Guangdong province. However, the growth in the rate of patenting by inventors in Guangdong province greatly outpaced overall growth in China for the next several years so that by 2006 applications from Guangdong accounted for nearly 50 percent of all applications from China to the USPTO. Guangdong's share has consistently remained at over 40 percent since then. Over the most recent period, the three dominant regions have been Guangdong province (45 percent) and the Beijing (21 percent) and Shanghai (14 percent) municipalities. These three regions currently account for 80 percent of all applications from China.

FIGURE 11. THE GEOGRAPHIC MIX OF APPLICATIONS FROM CHINA, 2000-12



As a measure of the concentration of the geographic mix in China, HHIs were calculated for each year from 2000 onward (see Figure A4 in Appendix). The results show that applications to the USPTO from China have become more geographically concentrated since the turn of the millennium. The most recent trends (from 2009 to 2012) seem to indicate that geographic

mix may be becoming less concentrated, although a similar trend between 2006 and 2008 quickly reversed itself.

According to one critic, the concentration of innovation in China is "fundamentally driven by agglomeration forces, linked to population, industrial specialization, and infrastructure endowment."[71] In "mature" innovation systems like the United States, patenting activity is spread among a greater number of regions than in emerging systems like China, where patenting is concentrated in Guangdong, Beijing, and Shanghai. However, it should be noted that geographic patent concentration in China is not much different from in the U.S., where the Silicon Valley region is responsible for 25 percent of issued U.S. patents.[72]

This polarization in China is enforced by an emerging trend among Chinese local authorities. These local authorities engage in territorial competition to attract external resources from both international investors and the Chinese central government. Authorities from these regions have more wealth and political power, and they promote the concentration of innovating activities at the expense of neighboring territories. Further, the enactment of Special Economic Zones in 1978 increased territorial concentration in Chinese innovation. This spatially concentrated FDI flows into a limited number of geographic zones and thus developed clusters of innovative activity in these regions.

These concentrations suggest that researchers looking for patterns and trends should focus on innovation within specific regions rather than examining it throughout the nation as a whole.[73] Other researchers have found that India displays similar geographic concentrations,[74] and future studies applying this approach could compare the booming technology centers of China with those of the comparison groups, such as similar technology producing clusters in India or South Korea, or even cities like San Francisco and New York.

D. *Foreign Co-Inventors in U.S. Patent Applications from China*

The influence of foreign companies doing business in China receives much attention. Many of these foreign companies are initially drawn to China for its attractive manufacturing environment and large domestic market, but they often expand their activities to include research and development projects and operations. To analyze the effects of these companies and their investments on Chinese development, first we examined U.S. patent applications from China that contain at least one foreign co-inventor. Sec-

71. Crescenzi et al., *supra* note 46, at 1055.

72. DRUID, *supra* note 26, at 01:07:25-01:08:01.

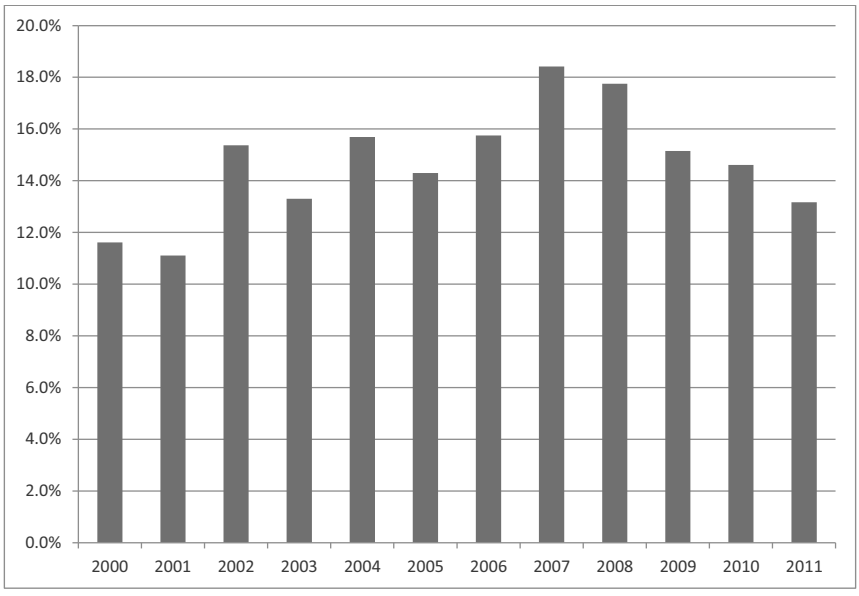
73. Indeed, Daniele Archibugi argues that countries may no longer be the relevant political unit in this area of study. DRUID, *supra* note 26, at 55:00-57:55.

74. Crescenzi et al., *supra* note 46, at 1057.

ond, we investigated the country or region of origin of the foreign co-inventor. Third, we compare the rates of having foreign co-inventors on patents originating China with the same rates from South Korea's high-growth period in the late 1980s and early 1990s.

Figure 12 shows the percentage of U.S. patent applications from China with at least one non-Chinese co-inventor by year of application for the years 2000 through 2011, which we use as a proxy for the level of foreign involvement in Chinese R&D. We have chosen to examine this scenario understanding that there may be many more patent applications involving all Chinese inventors working for multi-national companies in China. Hence, these figures represent a lower bound for joint research and development activities conducted by MNCs in China. For over a decade more than 10% of these Chinese patent applications contain a foreign co-inventor, and Figure 12 shows that this figure hovered around 18 percent in 2007 and 2008.

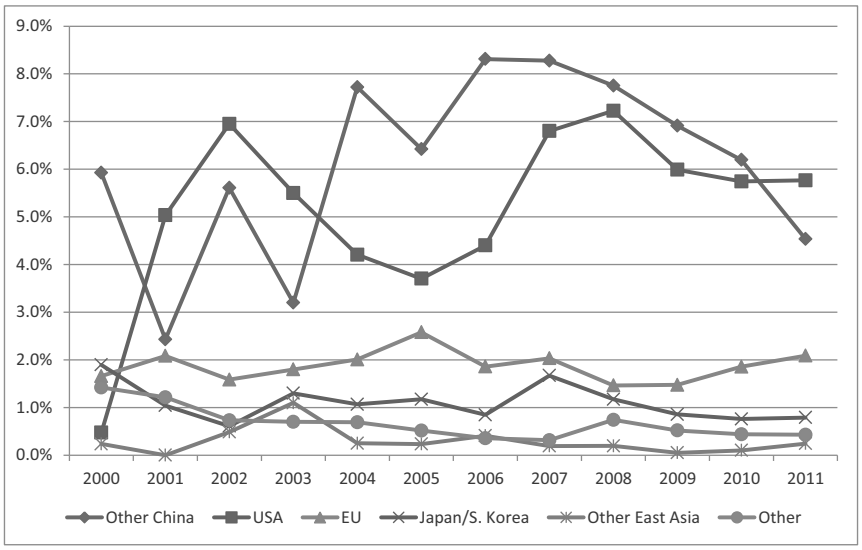
FIGURE 12. PERCENTAGE OF U.S. PATENT APPLICATIOS FROM CHINA WITH AT LEAST ONE NON-CHINESE CO-INVENTOR, BY YEAR OF APPLICATION, 2000-2011



We also analyze the country or region of the foreign co-inventor in Chinese patent applications in the U.S (see Figure 13). The major countries of origin for foreign co-inventors on Chinese patent applications are the United States, Taiwan, Hong Kong, and Macao. The European Union, Japan, South Korea, and other East Asian countries figure much less prominently (each less than 2 percent) as countries of origin for co-inventors. The results in Figure 13 clearly indicate that joint R&D activities that result in joint patent-

ing involve Chinese collaborations with the United States and with its nearest neighbors, namely Taiwan, Hong Kong, and Macao.

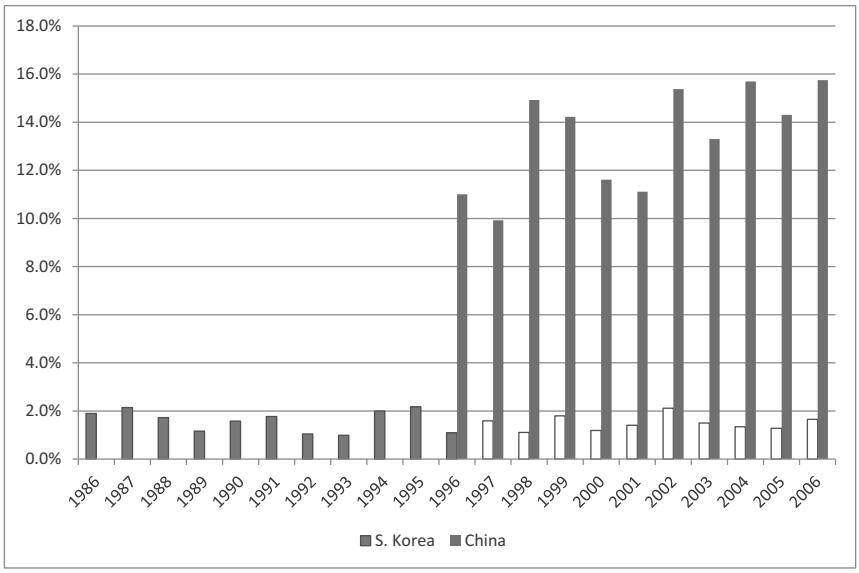
FIGURE 13. PERCENTAGE OF U.S. PATENT APPLICATIONS FROM CHINA WITH AT LEAST ONE FOREIGN CO-INVENTOR FROM VARIOUS COUNTRIES/ REGIONS, BY YEAR OF APPLICATION, 2000-2011



Note: "Other China" includes Taiwan, Hong Kong, and Macao
Note: "Other East Asia" includes the ASEAN countries and Mongolia
Note: EU includes all EU members plus Switzerland

We note that China and South Korea differ significantly when comparing the percentage of U.S. patent applications with foreign co-inventors from China with those coming from South Korea during its boom in Figure 14. Between 1986 and 2006—a period of high growth for South Korea—less than 2 percent of all U.S. patent applications originating from South Korea contained one or more foreign co-inventors. In contrast, for the corresponding high-growth period in China from 1996 to 2006 the percentage of U.S. patent applications from China with foreign co-inventors is much higher. During the entire decade this rate was always more than 10 percent, and it was typically between 12 and 14 percent. This indicates that MNCs currently have a greater interest in pursuing joint R&D activities in China than they did during South Korea's boom. It is also possible that with increasing globalization, MNCs are simply more willing to locate R&D activities in foreign locales in the 2000s than they were in the 1980s.

FIGURE 14. PERCENTAGE OF U.S. PATENT APPLICATIONS WITH AT LEAST ONE FOREIGN CO-INVENTOR DURING THE HIGH-GROWTH PERIODS FOR SOUTH KOREA AND CHINA



Note: The white bars indicate the results for South Korea for 1997-2006.

Even with globalization, the percentage of foreign co-inventors in U.S. patent applications from South Korea has remained under 2 percent for over two decades—during the entire period of 1986 to 2006. This figure is in sharp contrast with China, where the percentage of foreign co-inventors in the period between 1996 to 2006 has ranged between 10 to 15 percent, as shown in Figure 14. For the same high-growth periods, the percentage of foreign co-inventors in U.S. patent applications from South Korea compared to that from China is significantly different (See Figure 14). Our data and analysis support the view that, at least in part, the steadily increasing U.S. patent filings originating from China are spurred by MNCs engaging in joint R&D activities in China.

IV. IMPLICATIONS

Our results show that China's patenting trends at the USPTO have much in common with other East Asian technology booms. These commonalities are particularly striking when looking at the growth of South Korea in the 1980s. We are also able to observe the role of foreign direct investment, shifts in the technological focus, and geographic concentration. Our analysis provides helpful insights into possible future developments.

A. *Parallels Between China and South Korea*

It appears from our analysis that China is not exhibiting exceptional trends in technology innovation and in seeking patent protection. Instead, it is developing in a manner similar to other innovative countries in Far East Asia, primarily South Korea. In fact, the application trends from South Korea in the 1980s and the evolution of patenting characteristics in China are strikingly similar when application growth rates, patent allowance rates, and the technology mix of applications are considered.

The astronomical growth in the number of patent applications to SIPO from Chinese firms has been accompanied by similar growth in the number of applications to the USPTO from Chinese inventors. The number of applications to the USPTO from China grew at an average annual growth rate of 31 percent from 422 in 2000 to 10,511 in 2012. But the number of applications to the USPTO was already growing steadily before the turn of the century. Between 1997 and 2007, the average rate of growth was roughly 40 percent. As noted above, the increase in patent filings at the USPTO from Chinese inventors was likely influenced by several factors, including higher R&D investment, the Chinese government's aggressive patent reform efforts, and Chinese patent applicants' increasing familiarity with USPTO practices and regulations.

The rapid growth of Chinese inventors in U.S. patent filings is not unprecedented. The number of applications from South Korean inventors also increased at a yearly rate of roughly 40 percent from 1986 through 1996. In fact, using the South Korean experience as a guide, we should expect the number of Chinese applications to continue to grow steadily for at least the next decade (see Figure A5 in Appendix).

While the number of applications from China has increased over the past decade, so has the level of relative concentration of these applications in high tech areas such as computing, telecommunications, and electrical engineering. At the same time, the share of applications in biotechnology and chemical and material engineering fell from roughly 28 to 14 percent. Our historical analyses indicate that this trend had been ongoing since the mid-1990s. We found a similar result for other major emerging economies. In several of these economies, the share of computing and telecommunications applications grew substantially while the share of biotech and chemical engineering applications fell. The technology mix was more stable for Japan and South Korea, indicating that we may expect a more stable technology mix for Chinese applications as the Chinese economy matures.

Finally, the allowance rate for Chinese applications has steadily climbed in the past decade towards the allowance rates of South Korean and Japanese applications. For applications filed in the year 2000, we find that the allowance rate for South Korean and Japanese inventors exceeded the allowance rate for Chinese inventors by 10 percentage points (82 percent versus 72

percent). For applications filed in the year 2010 and disposed by February 2013, the difference between the two allowance rates was only one percentage point (79 percent versus 78 percent).

B. *Explaining Improvements in Allowance Rate*

An increased familiarity with USPTO procedures, and growth in capital investment and R&D expenditures have likely played large roles in improving patent application quality as measured by allowance rates. As SIPO's patent procedures have begun to mirror USPTO patent procedures, learning the new Chinese system provides a double benefit to Chinese inventors. Chinese applicants who follow these procedures have a better chance of having a patent application approved by SIPO, and they do not need to learn entirely new rules to submit successful applications to the USPTO. International collaboration has likely also contributed to increased success before the USPTO, as Chinese inventors often now work more closely with multinational enterprises and innovators who have years of experience applying for patents at the USPTO. In short, applicants who submit patent applications more successfully likely do so because of increased experience dealing with the USPTO or entities that follow similar procedures.

In addition to procedural factors, our analysis also highlights the role played by MNCs, who file a majority of the U.S. patent applications originating from China, and supports the work of other scholars who have emphasized the role played by outside entities in China.[75] As MNCs move beyond low cost manufacturing in China and start creating R&D centers in China to capitalize on highly educated, local Chinese talent, the production of innovative technologies in China will likely increase. To the extent that this is already occurring, it can partially explain the increase in patent quality suggested by our results.

The increase of high quality patent applications from Chinese applicants may also be a result of China's shift from discrete product industries to complex product industries. Our findings (see, for example, Figure A6) support this interpretation by highlighting the high rates of ATP exports from China compared to the rates of ATP exports from other emerging economies. This suggests that increased patenting activity in China is partly a result of Chinese businesses focusing on more complex products and services.

China is differentiating itself from its BRICS counterparts by seeking more patent protection, achieving higher allowance rates, and exporting more ATPs to the U.S. (see, for example, Figure A6). While the increased allowance rate suggests that Chinese patent applications have improved in quality, we cannot authoritatively state that the patents are of genuinely higher quality than earlier submissions by Chinese patent applicants until these patents have survived challenges in post-grant proceedings or patent

75. *See* Hu & Jefferson, *supra* note 29.

infringement lawsuits. Confirmation by the USPTO of the enforceability of these patents could encourage more innovation and patenting in China and throughout Asia by assuring new participants in the global economy that other influential governments will recognize and enforce their intellectual property rights.

V. Conclusions

The innovations of Chinese industries have caught the attention of global economic actors, making it likely that innovation in China will play a critical role in the trade, policy, and business decisions of governments and corporations. It is our hope that the data and analyses in this work can inform those decisions and fuel further research in this area. In this Article, we use the data to explore whether China's recent surge of patent activity is an idiosyncratic event or if it follows established patterns.

The two sets of data we analyzed focus on the number of patent applications submitted to the USPTO, the allowance rate of these applications, and the technology mix of these applications. The first set of data compares these figures for China, other BRICS countries, Japan, and South Korea from 2000 to 2014. The second set looks at China, India, and South Korea during their respective ten-year periods of highest patent application growth.

Our analysis indicates that China is following patenting trends similar to those exhibited by other East Asian countries, though at a more accelerated pace. Compared to other emerging BRICS economies, China is submitting more patent applications, the subjects of the applications are more sophisticated, and the patent allowance rate is more rapidly converging with that of developed economies like South Korea and Japan. China's current patenting trajectory is similar to other patent trends apparent from historical data, suggesting that China is not following a unique developmental path. If, however, we scale up the patterns observed during South Korea's highest growth period to China's size and level of economic activity, the data suggest that the growth observed in Chinese patent applications so far is only the beginning. Its patent application rates will probably continue to increase over the next decade before starting to slow.

The increase in Chinese patenting activity is therefore not without precedent, but our results suggest that increased R&D expenditures and the influx of foreign capital are more significant contributing factors that were not present in the same concentrations in other high-growth economies, such as South Korea. Therefore, while these developments are not an anomaly, they have also been enhanced by the nature of our increasingly globalized economy. Exposure to foreign direct investment and multinational corporations in China has contributed to a culture that accepts and relies on foreign intellectual property protections.

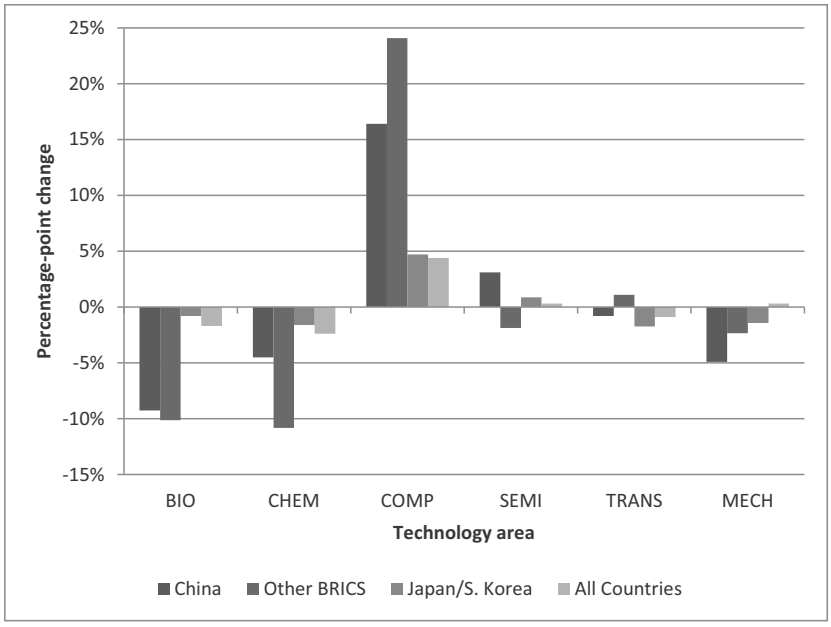
Our work also distinguishes Chinese technological development from more established economies by the geographic concentration of patenting activity within China. Increasingly, technological innovation is centered in especially innovative geographic clusters in the U.S., Europe, Japan, South Korea, and China. Future research should focus not just on innovation within a country as a whole, but also on innovation within observable clusters of inventive activity within these countries. In particular, our findings raise the possibility that the global innovative city is becoming the new model for sourcing technology innovation.

Future research should also explore factors responsible for rising patent allowance rates, especially evaluating whether the increased allowance rates are better explained by the effects of Chinese inventors becoming more familiar with the U.S. patent system or by increased collaboration with MNCs already familiar with the U.S. patent system. Other future work could supplement the comparative data discussed in this Article with economic indicators to examine where along the economic development spectrum this boom in innovation occurs. This type of analysis could potentially allow for projections of future patent booms.

In the future, U.S. patent litigation and licensing is likely to involve many more Chinese-owned U.S. patents. If the USPTO and courts uphold the validity of these patents, it is safe to say that the Chinese pursuit of patent protection in the U.S. is the new normal, cementing China's status as a global economic and innovative powerhouse.

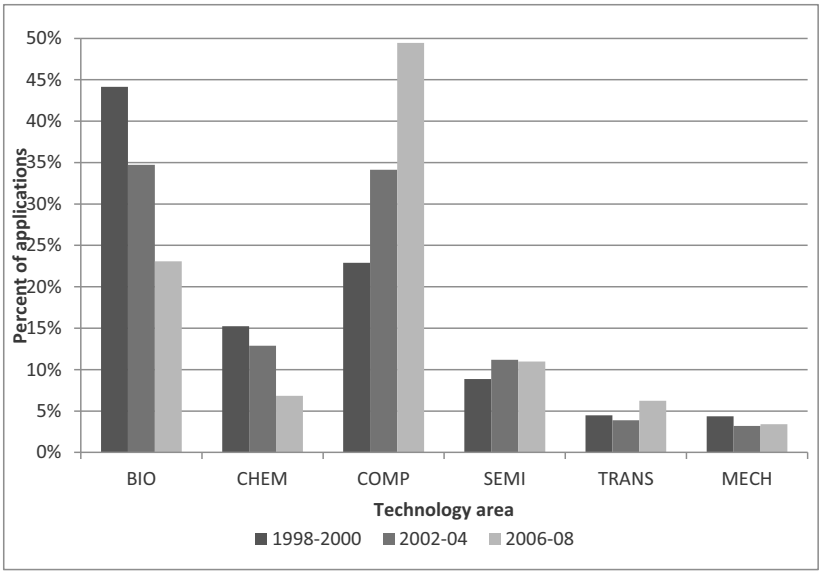
Appendix

Figure A1. Changes in Technology Mix of Applications From China and Various Comparison Groups, 2000-02 to 2010-2012



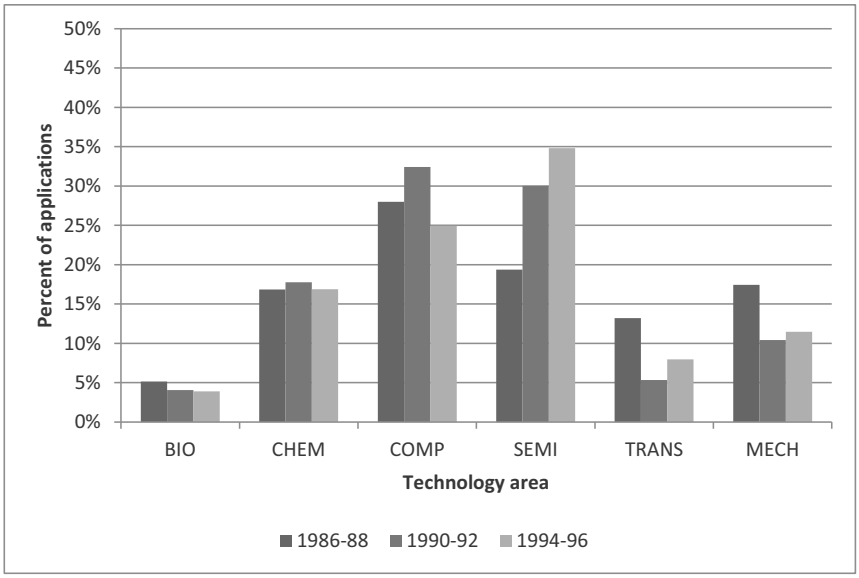
Source: Authors' calculations based on PALM data.

FIGURE A2. CHANGE IN TECHNOLOGY MIX, INDIAN APPLICATIONS TO THE USPTO, 1998-2008



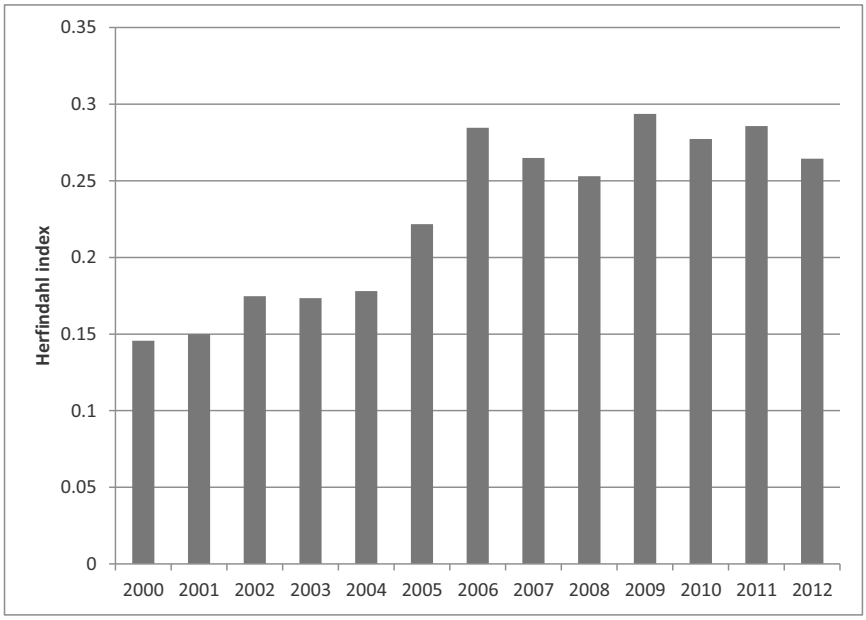
Source: Authors' calculations based on PALM data collected by the USPTO.

FIGURE A3. CHANGE IN TECHNOLOGY MIX, SOUTH KOREAN APPLICATIONS TO THE USPTO, 1986-1996



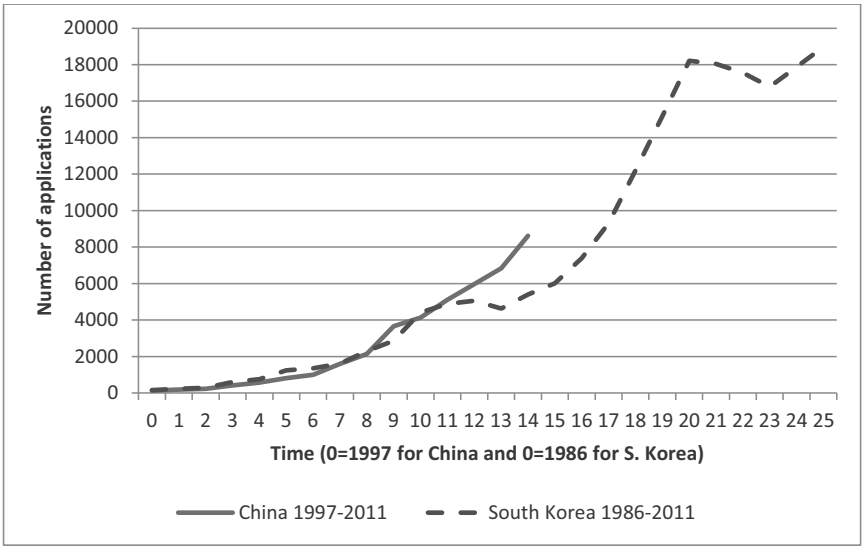
Source: Authors' calculations based on PALM data from the USPTO.

FIGURE A4. GEOGRAPHIC MIX CONCENTRATIONS OF APPLICATIONS FROM CHINA, 2000-2012



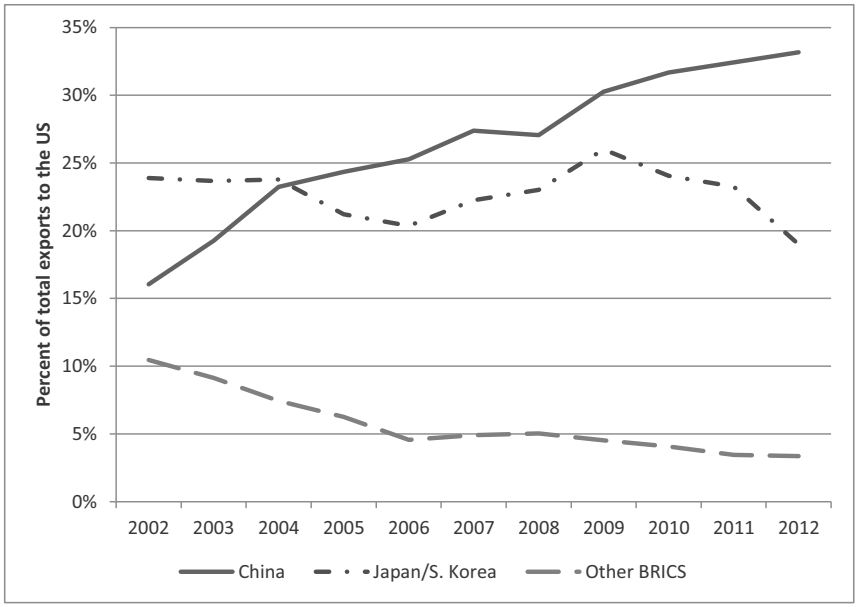
Source: Authors' calculations based on the geographic data for patent applications originating from China

FIGURE A5. THE NUMBER OF ANNUAL UTILITY PATENT APPLICATIONS FROM SOUTH KOREA (1986-2011) AND FROM CHINA (1997-2011)



Source: PALM data from the USPTO

FIGURE A6. SHARE OF TOTAL EXPORTS TO THE U.S. THAT ARE CLASSIFIED AS ADVANCED TECHNOLOGY PRODUCTS (ATPS), CHINA AND COMPARISON GROUPS, 2002-2012



Source: Authors' calculations using data from the Foreign Trade Division of the U.S. Census Bureau.