Slouching Tiger, Roaring Dragon: Comparing India and China as Late Innovators

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The challenges of late development have received scholarly attention for decades. As Gerschenkron's classic study of 19th century Europe argued, 'backward' economies face distinct opportunities and challenges, including the challenge of competition from more advanced economies (Gerschenkron 1962). In recent years, scholars have distinguished between latecomer development and latecomer innovation, and the particular challenges that the latter presents have come under scrutiny (Hobday, Rush, and Bessant 2004; L. Kim 1997; S.-Y. Kim 2012; Altenburg, Schmitz, and Stamm 2008). Simply put, it is one thing to become a 'fast-follower,' rapidly adopting the innovations of other countries, but quite another to go from fast-follower to innovation leader.

Despite the growing attention to latecomer innovation, we still lack a comprehensive theoretical framework to understand the policy challenges it presents. In addition, it remains unclear to what extent these challenges have changed in recent decades. After all, today's late innovators face a new international context: "the globalization of innovation" (Archibugi and Iammarino 2002; Ernst 2006). Leading firms from developed countries now frequently rely on overseas research and development (R&D) centers, as well as R&D alliances with firms from other countries, to develop new products. Developing countries are increasingly involved in these new transnational innovation processes. In 1990, for example, only 17 percent of U.S. R&D investment overseas was spent outside of Europe and Japan. By 2012, that figure had more than doubled to 35 percent (U.S. Bureau of Economic Analysis 2014c). In short, the challenge of late innovation – and how it is changing – deserves greater scrutiny.

To address these questions, this article develops a theoretical framework that outlines the basic policy challenges faced by late innovators today. Simply put, it argues that the governments of late innovators must not only encourage greater and more research-intensive R&D but also limit their role in the supervision of R&D. The success with which late innovators surmount these challenges, in turn, shapes the extent to which they emerge as innovation leaders in their own right. The globalization of innovation has not rendered these reform challenges less relevant or important; instead, it has raised the stakes for late innovators as they confront them. Late innovators that reform successfully are poised to profit from integration with global networks. Unsuccessful reformers, in contrast, will find such integration more difficult. The advent of global innovation thus has not changed the basic reform challenges that late innovators face. It does, however, offer greater rewards for countries that reform successfully – and new challenges for those that do not.

The article applies this theoretical framework to explain the recent experiences of China and India as late innovators. It has been popular in recent years to compare these two emerging powers as new sites of innovation in the world economy (Fuller 2014; Chaudhuri 2012; Dahlman 2010; Altenburg, Schmitz, and Stamm 2008). Even so, there is no consensus on how the two countries are faring (Kennedy 2015). This article finds that China's progress is more impressive on multiple fronts. Compared with India, China has confronted the basic reform challenges of late innovation more successfully, has more impressive innovation outputs, and has integrated into global networks more successfully. Even so, China's approach also has its weaknesses, and these are important obstacles to its emergence as an innovation leader.

The remainder of this article is organized as follows. The first section outlines a theoretical framework for understanding the policy challenges facing late innovators, particularly in an era in which innovation is globalizing. The second section compares how well China and India have confronted these challenges. The third section shows how China and India's different approaches have produced divergent outcomes in terms of innovation outputs, including both scientific publications and patents. The fourth section compares how China and India's distinct trajectories have positioned them within global networks. The article concludes by summing up the results and suggesting avenues for future research.

The Challenge of Latecomer Innovation

While late development can be viewed holistically, it is now popular to distinguish between distinct stages within this process. Scholars now distinguish between countries that are 'fast-followers' and those that are 'innovators' (S.-Y. Kim 2012), between 'imitation' and 'innovation' (L. Kim 1997) and between 'production' and 'innovation' (Altenburg, Schmitz, and Stamm 2008). In practice, of course, the dividing line between these categories can be rather blurry. Manufacturing firms in global production networks, for example, play a role in engineering new products. Moreover, the scope for innovation can grow as the transition is made from original equipment manufacturing (OEM), in which products are produced according to detailed designs, to original design manufacturing (ODM), in which only a basic design is provided in advance (Hobday 2000, 133–135). Nonetheless, there is an important distinction to be made between economies dominated by OEM and ODM firms on the one hand and innovation leaders on the other. The economies of the latter are led by the original brand manufacturers (OBM) that define and market new products.

Amsden and Tschang highlight the difference between followers and leaders by distinguishing between five different types of R&D (Amsden and Tschang 2003). Innovation leaders lead in three types of research: pure science, basic research, and applied research. The first of these seeks to uncover new scientific principles, the second pursues knowledge with the intention of creating wholly new products, while the third seeks to differentiate new products 'on paper.' In contrast, firms in latecomer economies focus on two forms of development. The first is exploratory development, which involves engineering a detailed prototype based on applied research. The second is advanced development, which entails generating a prototype for manufacture. The critical challenge for would-be innovation leaders, Amsden and Tschang argue, is stimulating their firms to move toward more research-oriented R&D. This is a multi-faceted challenge, as they note. It requires a more long-term perspective. It increases the need for Ph.D.-level researchers. It involves more emphasis on science and less on engineering. It requires a focus on the creation of intellectual property, as opposed to the acquisition of market share. The scale and expense of R&D increase as well.[1]

While there is no "perfect" example of this transition, a comparison of South Korea and Brazil's recent experiences is illuminating. In many ways, South Korea has embraced the challenge outlined above, while Brazil has struggled with it. It is not merely that South Korea devotes more resources to R&D, though this is certainly the case. In 2011, for example, South Korea's R&D spending culminated several decades of rapid growth by surpassing four percent of the country's GDP, while Brazil's R&D intensity languished around 1.2 percent (UNESCO 2014). It is also that South Korea's R&D is more research-oriented. Surveys of R&D typically distinguish between basic research, applied research, and experimental development – a simpler version of the typology developed by Amsden and Tschang. Between 1998 and 2006, South Korea's private sector devoted between 25 and 30 percent of its R&D spending to basic and applied research, with the balance shifting toward basic research over time (OECD 2009, 103). In contrast, Brazil's R&D spending tends to be driven by the public sector, and (with a few exceptions) the R&D done by firms tends to focus on process innovations aimed at lowering production costs (Bound 2008, 77). This is not surprising, since Brazilian firms are constrained by their personnel: a 2006 study noted that only 26 percent of Brazil's scientists worked in the business sector, compared with close to 80 percent in South Korea and the United States (de Brito Cruz and de Mello 2006, 12). All in all, while South Korea has struggled with some aspects of late innovation, it is clearly more successful than Brazil has been.

How can the governments of latecomer economies promote the transition to innovation leadership? Despite the important contributions that have been made, the literature on latecomer innovation has yet to offer a comprehensive framework that outlines an answer to this question. This article argues that there is a particular balance that governments must strike as they support national R&D. To be clear, the following discussion is not concerned with how governments can promote late development in general, which is a broader question.[2] Nor is this discussion concerned with all of the potential obstacles to innovation in a given economy. Instead, the following paragraphs highlight the balance that governments of late developers must strike with regard to the promotion of R&D if they aspire to innovation leadership.

The first priority entails encouraging greater and more research-oriented R&D on the part of firms – an 'R&D take-off' (J. Gao and Jefferson 2007). The potential for market failures to impede such investments have been appreciated for decades (Arrow 1962). In this case, the challenge is not simply encouraging R&D but also encouraging a shift in the nature of R&D, as described above. A number of scholars have shown how governments drive this process forward in late developers (Amsden and Tschang 2003, 564–71; L. Kim 1997, 21–58; Breznitz 2007; Samuels 1994). The specific measures have varied. Financial incentives to undertake R&D are an obvious tool. Greater support for university research and doctoral training is another measure, particularly given the need for more researchers equipped with Ph.D.s. Measures that encourage firms to collaborate in R&D can reduce risks and spread costs. And whereas weak protection of intellectual property can promote technology absorption and diffusion, stronger protection is needed to encourage greater investments in R&D. As a result of these and other measures, governments may create more R&D-intensive economies, while also encouraging a shift from development to research within national R&D activity.

While the first shift involves more active government, the second entails less active government. As scholars of late development have argued, the process of catching-up often involves greater government intervention in the economy, including support for specific sectors and firms (Johnson 1982; Amsden 1989; Wade 1990). At the technological frontier, however, such interventions can become problematic. The problem is not merely that there is an increased risk that government may back the wrong sectors or firms, since 'picking winners' is more difficult at the frontier. It is also that strong patron-client ties between government and the performers of R&D can develop, making connections – rather than merit – the key to winning support and denying opportunities to more innovative actors (Mahmood and Rufin 2005, 346). Such patron-client ties can complicate development in any developing economy, but they are particularly pernicious in would-be innovation leaders, since the entry of new and disruptive actors is so crucial to innovation (Olson 2008, 62–65; Mokyr 1990, 261; Mahmood and Rufin 2005, 346–347). Successful transitions, therefore, involve a retreating state. Fong provides a case in point by describing the receding role of the Japanese government in computer and semiconductor industries (Fong 1998). Wong argues that developmental states in Korea, Taiwan, and Singapore have retreated in an effort to pursue innovation leadership in biotechnology (Wong 2011). Focusing on Israel, Taiwan, and Ireland, Breznitz also argues that the state must be willing to accept a less prominent role (Breznitz 2007, 13–15). Other scholars concur with the notion that the interventionist policies appropriate for catch-up become problematic at the frontier (Drezner 2001, 19–22; Yeung 2014, 91; Dahlman and Andersson 2000, 41–42).[3]

The globalization of innovation has not reduced the salience of these two basic reform challenges. It has, however, created opportunities and dangers for late innovators that did not exist before (Ernst 2009). More specifically, globalization offers rewards for late innovators that reform successfully and punishments for those that do not. Let us first consider the former. Latecomers that reform successfully position themselves to profit from global innovation. Investments in more advanced human capital enable learning from multinational corporations, while also mitigating against the danger that domestic firms will be deprived of well-educated workers. Such investments also create the potential for domestic workers to make more substantial contributions in multinational innovation networks. Greater and more research-intensive R&D spending by domestic firms also facilitates learning, while creating opportunities for domestic workers outside of foreign firms. Government restraint, meanwhile, helps ensure that these investments are as productive as possible, rather than undermined by patron-client ties.

Latecomers that fail to reform, in contrast, are poorly positioned to exploit these opportunities. Instead, they risk succumbing to what Dieter Ernst has called the "poisoned chalice" of global innovation (Ernst 2009, 38). With a more limited supply of human capital, and smaller investments by domestic firms, there is less opportunity for learning, and the internal brain drain will loom larger as a problem. More limited human capital, along with weak intellectual property protection, also increases likelihood that foreign firms will conduct their more valuable R&D tasks elsewhere. Lastly, an interventionist government may compound these problems by reducing the productivity of the domestic investments that are made.

The two possibilities outlined above are ideal-typical, but they are useful as analytical tools, and they imply two very different developmental pathways. Latecomers that reform successfully should play growing roles in the production of original and valuable research. More specifically, national R&D in such cases should result in more scientific publications, as R&D becomes more science-based, and it should also result in more patents, as R&D becomes more focused on intellectual property. Foreign firms may play a role in national R&D in such cases, but not one that eclipses domestic firms. In contrast, latecomers that fail to reform will maintain lower profiles in scientific publications and patents. Foreign firms will be less eager to incorporate such countries into their innovation plans, and foreign R&D centers will be more likely to drain talent away from domestic firms.

The Governance Transition

How are China and India managing the two governance challenges associated with late innovation? The following discussion focuses first on efforts to encourage science-based R&D and then on efforts to limit the state's supervision of R&D. The discussion finds that China has outperformed India with regard to the former, but that both countries have struggled with the latter, although in different ways.

Encouraging R&D

Neither China nor India were leading R&D investors at the turn of the century. In purchasing power parity terms, China's R&D spending was about $30 billion, while India was just under $14 billion, compared with more than $300 billion in the United States. China's spending has exploded since then, however, while India's has increased more modestly. By 2011, China's R&D spending had reached $183 billion, while India's was slightly more than $32 billion, as shown in Figure 1 below.[4] Even if official statistics exaggerate China's R&D spending, it seems clear that China's total has increased much more rapidly than India's has.

Insert Figure 1 here

China's surging R&D spending reflects not only rapid economic growth, but also rising R&D intensity. In 2000, China devoted 0.9 percent of GDP to R&D (UNESCO 2014). By 2011, however, that figure had more than doubled to 1.84 percent – and then grew to 1.98 percent in 2012. In contrast, India devoted 0.74 percent of its GDP to R&D in 2000 and 0.81 percent in 2011.

China's rising R&D is led by business. In 2011, nearly 76 percent of China's R&D ($139 billion) was performed by business while another 8 percent ($14.5 billion) was performed by universities (UNESCO 2014). In contrast, the public sector still dominates India's national R&D spending; only 35 percent ($11.4 billion) of the country's R&D was performed by business in 2011, and only four percent ($1.3 billion) by universities. The prominence of Chinese businesses is becoming apparent globally. In 2012, China counted 93 companies among the world's top 2000 R&D spenders, led by Huawei (#31), Petrochina (#66), and ZTE (#94), while India only counted 22 firms in the mix (European Commission 2013).[5] In this respect, China is more in step with trends in developed countries, where business has become the primary engine of R&D. In recent years, business has accounted for about 60 percent of R&D spending among OECD member countries (OECD 2015).

In short, China appears to be in the process of an R&D take-off, while India is not. This difference reflects a range of factors. In China, a range of measures have aimed to increase R&D spending and R&D intensity. There are financial incentives, such as tax deductions for R&D expenditures, lower corporate tax rates for 'high-tech enterprises' (which must meet certain criteria with regard to R&D spending and other areas to qualify), and other measures (World Trade Organization 2014, 49). In addition, China had also set up 86 university science and technology parks by 2011, a number that was targeted to reach 200 by 2015 (Ministry of Science and Technology of the People's Republic of China 2011). Government pressure on enterprises, particularly central state-owned enterprises (SOEs), has played a role as well (Hu 2014). Starting in 2007, the State-owned Assets Supervision and Administration Commission of the State Council (SASAC), which formally owns and oversees China's largest SOEs, created incentives for managers to invest in technology inputs (Naughton 2012, 7). Predictably, spending increased: from 2006 to 2010, the SASAC firms increased their share of all intramural enterprise R&D from 33 percent to 38 percent (Li 2011, 27–28; China State Statistical Bureau 2013, 9). Even so, what the Chinese government calls "domestic private firms" – Chinese firms funded only by private individuals – increased their share as well over the same period, from 5 percent to 8 percent (China State Statistical Bureau 2011, 36; China State Statistical Bureau 2007, 199).[6] China's growing R&D spending, therefore, is not only driven by SOEs.

India's government has repeatedly stated its hope of raising the country's R&D intensity, but it has not had anything like China's success. While this is partly a function of India's lower level of development, there is more to the story here. In fact, India's R&D intensity has hardly changed since 1990, when the country's per capita GDP was less than a quarter of it what it is today (Brandt and Rawski 2008, 295; IMF 2014; World Bank 2015). Part of the problem is that India's programs to promote R&D have been plagued by a number of problems, which have limited the funds available and their availability to smaller enterprises (Krishnan 2010, 109–111). In addition, India's R&D

tax credit – while generous – has had limited impact because businesses struggle under an onerous and hard to predict regulatory environment. Smaller firms in particular devote significant resources to complying with (or avoiding) regulatory burdens, limiting the human and financial resources they have for investing in plants, machinery, and R&D (Ernst 2014, 43). Indian industry has also complained that the government does too little to inform entrepreneurs of the incentives that are available (Federation of Indian Chambers of Commerce and Industry 2014).

While China has outpaced India in promoting R&D spending, how do the two countries compare in terms of developing human capital and shifting the focus of R&D from development to research? There are some signs of progress in both cases. Both countries are granting more S&E doctorates than ever before. China's total increased dramatically from 7,766 in 2000 to 31,410 in 2010, while India's total increased more modestly over that period from 5,441 to 12,356 (U.S. National Science Foundation 2014, appendix table 2–42; Government of India 2013b). There is thus a growing supply of PhDs for research-intensive R&D in both countries, but China is moving faster in this regard. Both countries are also spending far more on basic and applied research in absolute terms than ever before: $34 billion in China in 2012 and $11 billion in India in 2009 (UNESCO 2014). Again, both countries are improving, but China's development is more impressive.

With regard to promoting more research-intensive R&D, China and India are having more difficulty, however. Since 2000, Japan and South Korea have both typically devoted from 30 to 40 percent of national R&D to basic and applied research (UNESCO 2014). The figure for the United States is comparable (U.S. National Science Foundation

2014, 0–19). In contrast, China devoted 22 percent of its R&D to basic and applied research in 2000, and only 16 percent in 2012 (UNESCO 2014). The research intensity of China's R&D is thus headed in the wrong direction. This decline may reflect the fact that firms now play a larger role in China's national R&D spending, and that business R&D is often less research-intensive than public or academic R&D. Even so, business looms just as large in national R&D spending in Japan and South Korea, yet these countries are clearly more research-intensive. India's R&D has become less research-intensive over time as well. From 1999 to 2009, the share devoted to basic and applied research fell from 46 percent to 38 percent (UNESCO 2014). Although the overall level is comparable to that in Japan and Korea, and considerably higher than that in China, this reflects the persistent dominance of government in India's national R&D spending, rather than a commitment on the part of business to conduct research-intensive R&D. In this regard, therefore, both China and India have some work to do.

The Role of the State

While investing in R&D is one matter, the direction of that investment is another. To make the transition to innovation leadership, the governments of late developers must retreat from a dirigiste role in the economy, allowing firms and universities to take the lead in defining the research agenda. This point is relevant in both the Chinese and Indian cases. In both countries, the government was heavily involved in R&D decisions for decades following World War II. In China's case, the communist system precluded a private role in R&D, and the initial focus on nuclear weapons and missile technology left little room for other programs in any event. In the 1980s, China shifted to a more civilian focus, but the state continued to control where investments were made (Feigenbaum 2003, 164–188). In India's case, nuclear and missile technologies also attracted great interest initially, but the state remained in control even outside these areas (Kennedy 2012, 204–205). The Indian government set up a network of national laboratories under the Council of Scientific and Industrial Research (CSIR), and these labs were charged with developing technologies to reduce the need for technology imports. This focus on import substitution continued into the 1980s. In both China and India, then, the state was highly involved in R&D throughout the Cold War period.

In recent decades, both China and India have moved away from the state-led model, but both countries have also struggled with this process, albeit in different ways. Let us start with China. China's rapid shift to a system in which enterprises account for most of the country's rapidly growing R&D spending is striking. Nonetheless, the state-led model has not simply been abandoned. In 2006, China's State Council released the 'National Medium- and Long-Term Program for Science and Technology Development (2006-2020),' or MLP, which touted itself as a 'grand blueprint of science and technology development' for the country until 2020 (State Council of the People's Republic of China 2006). Leading up to the MLP's release, prominent Chinese economists had cautioned the government about becoming too involved in technological choice (Chen and Naughton 2013, 14). In addition, eminent Chinese scientists called for an open funding system based on peer review, warning that otherwise China would 'get half the result with twice the effort' (Rao, Bai, and Tsou 2004, A12). In the end, however, control of the research agenda remained firmly in the hands of government officials. In fact, the MLP prioritizes eleven 'key areas' and eight 'frontier technologies for support. The plan also promotes 16 'megaprojects' in particular, which range from manned space flights and lunar exploration to genetically modified organisms.[7] The latter are clearly a legacy of science planning in China (Cao, Suttmeier, and Simon 2006, 40). Each of the megaprojects is supervised by a leadership small group, each of which includes representatives from multiple ministries (Chen and Naughton 2013, 15–16). Funding for the megaprojects has grown quickly. It was less than US$1 billion in 2008, but more than US$8 billion was allocated for 2014 (Qiu 2014; Chen and Naughton 2013, 17).

In 2010, the Chinese government unveiled a new plan: the 'Strategic Emerging Industries' (SEI) initiative. The initiative targeted seven areas, including next generation information technology, bio-technology, high-end equipment manufacturing, new energy, new materials, new energy automobiles, and energy and environmental conservation. The SEI was not intended to replace the MLP but to complement it, converting technological progress from the megaprojects into concrete commercial outcomes. In addition, the SEI differed from the MLP by envisioning a broader role for government: whereas the megaprojects are government-funded, the SEI relies not only on public funding but also on more general efforts to create favorable conditions in which the emerging industries can grow (Chen and Naughton 2013, 19). The Chinese government even stipulated how rapidly these sectors should develop. As of 2010, the seven sectors accounted for two to four percent of China's GDP (Naughton 2011, 325). The circular announcing the SEI stated that these sectors would contribute eight percent of China's GDP by 2015 and 15 percent by 2020 (State Council of the People's Republic of China 2010). The initiative was subsequently incorporated into China's 12th Five-Year Plan.

The Xi Jinping-Li Keqiang government has shown interventionist tendencies as well, despite market-friendly rhetoric. In 2014, China unveiled a $19 billion investment fund to support the development of microchips, which have become a major import item for the country (Y. Gao 2015). The new fund attracted intense interest from Chinese companies, but how well they can exploit this opportunity remains to be seen. In 2015, China unveiled yet another grand plan: "Made in China 2025." The goal is to modernize China's manufacturing sector by making it more innovative, more environmentally friendly, and more focused on quality. According to the State Council's official notice, the program will be "market-led" and only "government guided" (State Council of the People's Republic of China 2015). Yet the notice also says that China should "vigorously promote breakthroughs in key areas" and proceeds to list 10 such areas.[8] The notice also includes a timeline for development, with quantitative targets set for 2020 and 2025. In short, the Chinese government is still clinging to its role in directing national innovation. Recent descriptions of China as a complex, "multi-driver" system seem appropriate (Fu 2015, 388).

While India has not promulgated grand plans as China has, it has reformed its national R&D system more slowly than China has. Most of the country's R&D is still funded by the government, as noted above, and the majority of this goes to the strategic sectors of space, atomic energy, and defense. To be sure, there have been significant reforms. Reforms to CSIR in the 1980s, coupled with the liberalization of the Indian economy in the early 1990s, shifted the focus away from technological self-reliance and toward performing cutting-edge R&D that is relevant to industry (World Bank 2007, 64). Laboratories became more autonomous and focused on tangible outputs, such as publications and patents, with the National Chemical Laboratory a particular success (Krishnan 2010, 121; Kale and Little 2007, 605). CSIR's collaboration with industry has also been spurred by the New Millennium Indian Leadership Technology Initiative. This scheme, piloted in 2001 and fully introduced in 2003, promotes public-private partnerships (PPP) in high-risk technology development, and the program has been expanded over time. India's public R&D, then, has become more responsive to the market.

India still has far to go in this regard, however. The government's 2013 Science, Technology, and Innovation policy noted that the 'rigidity of centrally developed plans for investments' was often at odds with 'frontline science, technology development and innovation' (Government of India 2013a, 13). Or as a former chair of India's Atomic Energy Commission has put it more bluntly, "science and technology R&D investments in India are predominantly public sector driven with little input from the private sector, which seriously needs to change" (Pulakkat 2015). Indeed, businesses still complain that programs at public research institutes are not aligned with the needs of industry. To address the problem, they have called for the institutes to create formal advisory boards with representatives from industry, and they have also suggested ways in which the Indian government can better promote R&D in the private sector itself (Federation of Indian Chambers of Commerce and Industry 2014, 2). Scientists, meanwhile, complain of excessive bureaucratic control over their research activities, and of crippling and seemingly arbitrary funding cuts that can take place mid-year (Pulakkat 2015). Prime Minister Narendra Modi has vowed to improve matters, and his government has begun soliciting input for a new S&T policy, "Vision S&T 2020" (Government of India 2014b).

It remains to be seen what the new policy will entail, however, and how effectively it will be implemented.

To sum up this discussion of reform as a whole, it is apparent that China and India have taken different approaches to the challenge of late innovation. China has made a concerted and impressive effort to increase national R&D intensity, and its R&D system has become more market-led as businesses have come to the fore. Even so, the Chinese government has shown a continuing proclivity to direct – or at least to attempt to direct – where R&D investments are made. India, in contrast, has struggled both to increase the R&D intensity of its economy and to foster a more market-led system, though it has made some progress with regard to the latter. With these contrasting profiles in mind, let us turn to innovation outputs.

Innovation Outputs

How do China and India compare in innovation outputs? The following discussion finds that China and India's performance in these two areas is broadly consistent with their R&D governance. Overall, it finds that China has outpaced India in keeping with its much greater investment in R&D. Yet it also finds that China's performance is constrained by the aspects of its system that remain state-led, which have fostered the emergence of problematic patron-client ties.

Scientific Publications

Since the turn of the century, China's share of academic science and engineering (S&E) articles has exploded. In 2001, China's share of articles in the Thomson Reuters

Science Citation Index and Social Science Citation Index was a mere 3.4 percent. By 2011, however, it had reached 10.9 percent – second only to the United States. Most of China's growth has come in the fields of chemistry, which accounted for a quarter of China's S&E articles in 2011, followed by physics, engineering, and biological sciences. India's share of S&E publishing has increased as well, but more modestly: from 1.7 percent in 2001 to 2.7 percent in 2011 (U.S. National Science Foundation 2014, 5–38).

Quantity is not the same thing as quality, of course, when it comes to academic publishing. Even so, it is also apparent that China is making great strides in scientific publishing. Data on highly cited papers are revealing in this regard. According to Thomson Reuters Essential Science Indicators, 13.1 percent of highly cited (*i.e.*, among the 1 percent most cited) S&E papers published between 2009 and 2013 included an author from China. That was comparable to the figures for Germany and England, and more than double China's corresponding figure for 2004-2008. India's share of highly cited papers has risen as well, though only from 1.4 percent to 2.0 percent (see Figure 2 below).

Insert Figure 2 here

Chinese scientists have also emerged as recognizable leaders in specific fields. This can be discerned from their growing importance in what Thomson Reuters calls 'research fronts' – specific areas of inquiry (such as the impact of climate change on food crops). In some fronts, Chinese scholars account for a substantial slice of the 'core papers' – the foundational and most frequently cited papers within the front. China accounts for 30 core papers in the study of a new class of superconductors, for example, with the U.S. accounting for 15 and Germany for seven (King and Pendlebury 2013, 18–19). In another front that is relevant to cancer research, Jasmonate biosynthesis and signaling, the U.S. leads with 15 core papers, but China boasts the second-highest total with eight (King and Pendlebury 2013, 6–7).

In short, China has outpaced India with regard to S&E publishing in general. Nonetheless, serious problems remain in Chinese science. Some of these, such as plagiarism and risk-aversion, reflect government pressure to demonstrate productivity on an almost annual basis (Qiu 2014). Yet the government's direction of science funding has held China back as well. Some of the smaller grants, such as those from the National Natural Science Foundation, are awarded on the basis of merit. Larger grants associated with the MLP's megaprojects, however, are often awarded on the basis of connections with government officials. As Chinese scientists have described the process, officials in funding agencies exercise their influence by appointing committees of experts to develop application guidelines each year (Shi and Rao 2010). These committees are typically composed of favored scientists, and they often draw up guidelines that advantage scientists or laboratories that have strong connections with the government. As a result, researchers devote an inordinate amount of time and energy to cultivating relationships with government officials, and funds are frequently disbursed on the basis of personal connections rather than merit. In this context, it is not surprising that a recent audit has disclosed rampant misuse of scientific research funds in China (Qiu 2014). In short, there is clear evidence of problematic patron-client ties in this case – a direct result of the state's involvement in managing R&D spending. Notwithstanding China's great progress, then, there is much room for the management of Chinese science to improve.

Patents

The explosion of patenting activity in China in recent years has received no little attention. In 2013, China's State Intellectual Property Office (SIPO) received 2.38 million applications and authorized 1.31 million of these (Xinhua 2014). Many of China's patent applications are for utility model patents – a category for minor innovations in which lower standards are applied. In 2013, however, China received 825,000 applications for invention patents – a total that was up more than 26 percent from the year before. In contrast, only 43,674 patent applications were filed in India in 2012-2013, and 16,061 were granted (Government of India 2014a). Such stark contrasts are part of the reason China and India fare so differently in the Global Innovation Index. In 2014, the Index ranked China 29th and India 76th in the world, respectively (Cornell University, INSEAD, and WIPO 2014).

Straightforward comparisons of national patent data are rife with problems, however. This is particularly the case with China, since the quality of its patents remains in question. The Chinese government has offered a range of incentives to boost patent applications and patents granted in recent years (Liang 2012, 486). While this has had the desired effect, not all applications are serious, and some are submitted for ideas that are not expected to generate economic value (The Economist 2010). The level of scrutiny that patent applications receive is another variable. One study estimated that each patent agent in China spent an average of 2.5 days on each application in 2009 – a remarkably short amount of time and well below the average of 18 days estimated for the U.S. (Liang 2012, 510). Even the state-run *China Daily* characterizes China's patent boom as 'high quantity, low quality' (*China Daily* 2014). To gauge national innovation activity, therefore, we need more comparable data.

One useful approach is to compare countries in terms of triadic patents. A triadic patent family is a set of patents covering the same invention that has been granted by the U.S. Patent and Trademark Office (USPTO), the European Patent Office (EPO), and Japan's patent office (JPO). Triadic patents thus reflect uniform, and relatively high, standards of evaluation. In addition, triadic patents generally represent more important innovations, because inventors are more likely go to the added trouble and expense of pursuing protection in multiple markets if the invention is deemed particularly valuable. Figure 3 below shows triadic patent data by inventor's country of residence for China and India between 1999 and 2012. China's total has increased rapidly to nearly 1,000 triadic patents in 2012. While this remains well short of the U.S. figure for that year (12,722), the trend is impressive. In contrast, while India's total has increased, it has done so at a much more moderate pace. Moreover, India's rate of increase appears to have slowed after 2010. To sum the two trends up differently, China's total increased by a factor of 9.9 between 2001 and 2012, while India's increased by factor of 1.8.

Insert Figure 3 here

In both China and India, employees of foreign firms account for most of this triadic patenting activity (Branstetter, Li, and Veloso 2014). If we focus on the overseas patenting of Chinese and Indian firms, however, China is still well ahead. The top Chinese firms have not only invested heavily in R&D but also made aggressive efforts to protect their intellectual property. Huawei's prolific patenting is well-known: by the end of 2012, the firm had been granted more than 30,000 patents worldwide (Huawei 2014). In 2013, the firm applied for 1,149 more patents from USPTO (U.S. Patent and Trademark Office 2014). Yet Huawei is not the only Chinese firm seeking patents overseas. In 2013, Tencent, Lenovo, and Alibaba applied for 248, 134, and 88 patents from USPTO, respectively. Overall, Chinese firms have more than twice as many patents with USPTO as their Indian counterparts (Branstetter, Li, and Veloso 2014).

Indeed, India's top technology firms have not traditionally emphasized creating their own intellectual property. This is most apparent in IT. Indian IT service providers generally offer personnel and expertise to support the R&D of other companies, particularly American companies, rather than investing in their own IP. Wipro's annual report for 2012-2013 disclosed that the firm spent only 0.6 percent of IT services revenue on R&D (Wipro 2013). As of January 2014, however, the company had five to six thousand employees in 'product and engineering services' – providing software and other services to support to new product development for other firms (Srivastava 2014). It is for this reason that the firm describes itself as a global leader in 'outsourced R&D' (Wipro 2013, 3). Infosys has traditionally stood out for spending more on R&D than other Indian IT firms, but the company now appears to be cutting back. It devoted 2.5 percent of revenue to R&D in 2013 but only 2.0 percent in 2014 (Infosys 2014a). This de-emphasizing of R&D is also evident in the downsizing of Infosys Labs, which describes itself as 'defining and driving the research and innovation agenda at Infosys'

(Infosys 2014b). In 2013, the Labs' staff was reduced from 600 to between 300 and 350 personnel in order to increase staffing on billable projects (Subramanian 2014). India's pharmaceutical companies offer a somewhat different example. These firms have traditionally specialized in generic drugs, rather than wholly novel medicines. Some are now trying to become more creative and to move up the value chain: Dr. Reddy's Laboratories has established an R&D facility in Princeton, New Jersey with this purpose in mind. Yet this remains a nascent development, and patent applications thus remain relatively low as well. In 2013, Dr. Reddy's applied for 7 patents from USPTO (U.S. Patent and Trademark Office 2014). The figures for the Indian firms Ranbaxy and Lupin were 11 and 2, respectively.

Nonetheless, while Chinese firms are ahead of their Indian counterparts in the pursuit of intellectual property, problematic patron-client ties bedevil China's corporate innovation system. In the consortia that conduct megaproject research, for example, prominent SOEs have taken a greater role than other types of companies, even though these state enterprises are not China's most innovative firms. Whereas SASAC firms accounted for more than a quarter of national R&D spending in 2010, they accounted for only 9 percent of domestic patent applications and only 6 percent of patents received (Naughton 2012, 12). China's SOEs are also laggards in terms of patenting overseas, particularly when compared with firms like Huawei and ZTE, which were founded without investment from the central government. In short, while Chinese megaproject largesse gives a privileged role to SOEs, these are not the most innovative firms in the Chinese economy, even if foreign firms are excluded. In this context, it is not surprising that more dynamic firms that are involved in the megaprojects, such as Huawei, have complained about the restrictions and stated that they would prefer a more open system that allowed more collaboration with foreign firms (Liu and Cheng 2011, 34).

Roles in Global Innovation

In a variety of ways, China and India have come to play more prominent roles in global innovation in recent years. As described below, foreign multinationals have established a growing number of R&D centers in China and India, while some Chinese and Indian companies are collaborating with foreign firms in R&D alliances. Chinese and Indian firms have also begun to invest in overseas R&D centers as well. These developments have not fundamentally changed China and India's trajectories as late innovators, however. Instead, the success with which China and India have confronted the basic policy challenges facing late innovators has shaped the nature of their integration into global networks. Consistent with its more successful reforms, China has integrated into more successfully into these networks than India has. China has attracted more interest from foreign firms, it is playing a more important role in global innovation overall, and it is less constrained by the internal brain drain challenge. Even so, China's record is hardly untarnished, as the following discussion will show.

Let us begin with China and India's relative prominence in global innovation. Despite the nationalistic tone of China's MLP and SEI initiatives, the Chinese government has welcomed collaboration with foreign firms in R&D in recent years (Kennedy 2013). While India also welcomes such collaboration, most estimates indicate that China hosts more foreign R&D centers than India does. One recent study, which focused on the 500 multinationals that spend the most on R&D worldwide, found that

385 had centers in China while 228 had centers in India (Zinnov 2013). China is also more active than India in terms of concluding transnational R&D alliances. Between 2000 and 2014, Chinese organizations concluded 200 such alliances, while their Indian counterparts concluded 105 (Thomson Reuters 2015). If we focus just on more recent years (2010-2014), the numbers still favor China, 47 to 18.

If we focus on the nature of the R&D that multinationals are doing in China and India, it is difficult to generalize. In both countries, there are examples of impressive, global-facing R&D efforts. Microsoft Research Asia in Beijing, for example, does world-class research in areas ranging from user interface, multimedia, data intensive computing, search, and computer science fundamentals (Lo 2014). For its part, Cisco India represents a major R&D effort featuring 17 of the company's 84 top engineers as of early 2014 (*The Economic Times* 2014). In other cases, however, the work is simply designed to adapt existing products to local markets. One prominent global wind power firm, for example, re-designed its gearbox in China to make it less expensive, but in doing so it cut the durability of the product in half (Anonymous 2013a). Overall, however, recent research suggests that more impressive work is being done in China. This research has compared the quality of patents (as measured by forward citations) filed with the USPTO by China-based and India-based employees of multinational firms (Branstetter, Li, and Veloso 2014, 29). The results indicate that patents associated with Chinese inventors are of higher quality than those associated with Indian inventors. In fact, if one compares patents within the same company, those featuring Chinese inventors are equivalent in quality to those produced exclusively by inventors resident in the firm's home country. There appears to have been rapid improvement in the quality of patents filed by China-based employees of multinationals, but not in the patents filed by India-based inventors.

But if foreign firms are doing more work – and more important work – in China than in India, China's more successful promotion of R&D means that Chinese firms are better positioned to compete for domestic talent than Indian firms are. In the past, to be sure, Chinese scholars and officials have worried that foreign firms were luring the country's best and brightest away from domestic firms and research institutes (Breznitz and Murphree 2011, 106; Schwaag-Serger 2009, 59–60). These worries have receded in recent years as Chinese start-ups have become more prevalent and attractive and as salaries at Chinese firms have risen (Anonymous 2013b; Murphy and Lin 2014). In India, in contrast, domestic employers struggle to compete. Multinational R&D centers pay up to 10 times what Indian government labs do, so the foreign companies routinely hire the best talent (Ernst 2014, 36). Indian businesses have difficulty competing in part because their R&D budgets are so limited. In 2011, for example, Indian businesses spent only $11.4 billion on R&D, as noted above. That same year, U.S. firms alone spent $2.1 billion on R&D activities in India – nearly 20 percent of the Indian total (U.S. Bureau of Economic Analysis 2014b). The R&D work in foreign firms, meanwhile, often has little relationship with the local Indian economy. India has impressive chip design capabilities, for example, but its talent is contained within foreign firms, which are focused on export markets, so little of this capability is disseminated locally (Ernst 2014, 7).

China is also making a bigger impact in global networks as its technology firms invest overseas. R&D spending by Chinese firms in the U.S., for example, has increased rapidly from virtually nothing in 2007 to $366 million in 2011 (U.S. Bureau of Economic

Analysis 2014a). While R&D spending by Indian firms has increased as well, it has done so more modestly, from $6 million to $39 million, over the same period. California in particular has been a magnet for Chinese IT companies, with both Huawei and ZTE opening R&D centers in the state in recent years (Rosen and Hanemann 2012, 35 and 50). While data for Chinese and Indian R&D spending in the EU are not available, Chinese FDI in Europe more generally in recent years has outpaced Indian levels, and it is clear that China's investments include R&D centers (Eurostat 2015; Di Minin, Zhang, and Gammeltoft 2012). As of 2013, for example, Huawei's 16 R&D centers overseas included centers in Germany, Sweden, France, and Italy (Huawei 2014).

While China is integrating more successfully into global innovation networks, its track record is hardly unblemished. There is strong dissatisfaction on the part of many foreign businesses with the extent of industrial espionage in China today, which in some cases appears to be state-sponsored (Mandiant 2013). While there are concerns about intellectual property protection in India as well, a report published by the U.S. intelligence community in 2011 called China and Russia "the most aggressive collectors of U.S. economic information and technology" (United States Office of The National Counterintelligence Executive 2011, 4). This concern may be affecting where foreign firms invest in R&D. Prior to 2010, U.S. firms consistently spent more on R&D in China than in India. Since 2010, however, India has taken the lead. In 2012, for example, U.S. firms spent $2.3 billion in India, compared with $2.0 billion in China (U.S. Bureau of Economic Analysis 2014c). In terms of specific sectors, India has narrowed the gap with China in manufacturing R&D, and it has overtaken China in "professional, scientific, and technical services," a category that includes computer systems design and software development (U.S. Bureau of Economic Analysis 2014c). To be sure, there may be multiple reasons behind these shifts, and China concluded an agreement with the United States in 2015 to address concerns about its industrial espionage. Even so, serious concerns persist, and the extent to which the agreement will reduce them in the future remains unclear (Shalal 2015).

Conclusion

This article has argued that late innovators face two basic policy challenges. On the one hand, they must encourage greater and more research-intensive R&D spending. On the other hand, they must limit government supervision of R&D. The success with which late innovators confront these challenges, in turn, shapes their performance in the production of original and valuable research. The globalization of innovation has not rendered these challenges less important; on the contrary, it has raised the stakes for late innovators as they confront them. Late innovators that reform successfully are poised to profit from global integration, while the unsuccessful will find such integration more challenging.

This theoretical framework illuminates the recent experiences of China and India as late innovators. Overall, China's reform effort has been more successful. In particular, China has been far more successful at encouraging greater R&D spending, particularly among enterprises, and it has generated a greater supply of human capital in S&E fields. Consistent with this difference, China has performed more impressively than India in scientific publications and patenting activity. Generally speaking, China has also integrated more productively than India has into global innovation networks. Yet China has also paid a price for the government's continuing intervention in the management of R&D. There is evidence of problematic patron-client ties both in scientific research and in corporate innovation. Such problems limit the efficiency with which R&D spending is translated into innovation outputs, and this weakness may become more serious in years to come, especially if China's economy continues to cool and resources become more constrained. In addition, the extent of industrial espionage in China in recent years has generated considerable alarm among foreign firms, which may limit how prominent the country becomes in global innovation in the future.

These findings speak to other studies that have explored the political economy of innovation in China and India in recent years. With respect to China, this study agrees with recent critiques of the government's nationalistic management of R&D policy (Breznitz and Murphree 2011; Naughton 2011). It also accords with studies that have criticized China as preoccupied with increasing inputs to innovation rather than the efficiency with which these inputs are used (Deiaco and Jeding 2015; Fu 2015, 350–52). It disagrees with the notion that China is mired in 'technological stagnation,' however, as its most ardent critics have suggested (Beckley 2012, 69). Instead, this study suggests that China has made remarkable progress in some respects, even as it has struggled in others. With respect to India, this study concurs with recent critiques of the government's failure to promote R&D more effectively (Krishnan 2010, 61–140). It also concurs with studies that have contrasted Chinese and Indian corporate business models and linked them to national innovation performance (Chaudhuri 2012). It does not fault Indian firms for following less ambitious paths, however, but rather highlights the incentives they face and the environment in which they are operating. The study also challenges the idea that India needs to emulate China's interventionist approach to R&D management. It is China's encouragement of R&D in general that India ought to emulate, not its micromanagement of where investments are made.

Future research should explore in more detail the conditions that give rise to successful transitions in late innovators. More research on the role of regime type would be particularly welcome. Is it the case that autocratic or post-communist governments are more capable of generating an R&D take-off, but that they also tend to intervene in R&D management, as the Chinese case suggests? Or is this outcome dependent on other factors that distinguish China from India? In addition, more research on how global innovation networks promote or constrain development in late innovators is warranted. While a number of recent studies have explored the spillover effects of foreign R&D centers in China and India, there is no consensus at present as to the net benefits for host economies (Fu and Gong 2011; Marin and Sasidharan 2010; Basant and Mani 2012; Quan 2010). This study has argued there is no uniform effect; success and failure depend upon the kinds of reforms adopted by the host country. In that sense, it demonstrates that today's late innovators are not at the mercy of multinationals, but retain an important degree of agency as they strive for technological leadership.

Notes

[1] Amsden and Tschang note that the first government labs in latecomer economies typically focused on basic or applied research and preceded centralized R&D in private firms. Their point is not that such efforts must be revived, since they were typically unproductive or focused on defense priorities, but that firms must move beyond a preoccupation with forms of R&D that are tightly coupled to manufacturing (Amsden and Tschang 2003, 557).

[2] Scholars often note that access to foreign technology is an important ingredient in late development *and* late innovation, for example. The focus here, however, is on new challenges that late developers confront as they seek to become innovation leaders.

[3] One recent study of mobile broadcasting in South Korea (S.-Y. Kim 2012) suggests that government may not need to retreat so much as develop more specialized, expert agencies that can manage innovation in specific areas. This solution appears highly demanding in terms of government capacity, however, making it difficult to replicate.

[4] Following the practice of the U.S. National Science Foundation, this article relies on UNESCO R&D data because it makes spending figures available in constant dollars and purchasing power parity terms.

[5] China's total did not include various Chinese firms incorporated in the Cayman islands, such as Tencent (#195) and Baidu (#322).

[6] These data are for large- and medium-sized private firms in particular.

[7] Three of the projects have not been disclosed and are believed to serve military purposes.

[8] The areas include new information technology, numerical control tools, aerospace equipment, high-tech ships, railway equipment, energy conservation, power equipment, new materials, medicine and medical devices, and agricultural machinery.

References

Altenburg, Tilman, Hubert Schmitz, and Andreas Stamm. 2008. "Breakthrough? China's and India's Transition from Production to Innovation." *World Development* 36 (2): 325–44.

Amsden, Alice H. 1989. *Asia's Next Giant: South Korea and Late Industrialization*. New York: Oxford University Press.

Amsden, Alice H., and F. Ted Tschang. 2003. "A New Approach to Assessing the Technological Complexity of Different Categories of R&D (with Examples from Singapore)." *Research Policy* 32 (4): 553–72.

Anonymous. 2013a. R&D employee, personal interview by author, Beijing, July 4.

———. 2013b. Chinese central government official, personal interview by author, Beijing, June 25.

Archibugi, Daniele, and Simona Iammarino. 2002. "The Globalization of Technological Innovation: Definition and Evidence." *Review of International Political Economy* 9 (1): 98–122. doi:10.1080/09692290110101126.

Arrow, Kenneth. 1962. "Economic Welfare and the Allocation of Resources for Invention." In *The Rate and Direction of Inventive Activity: Economic and Social Factors*, 609–26. Princeton: Princeton University Press for National Bureau of Economic Research. http://www.nber.org/chapters/c2144.pdf.

Basant, Rakesh, and Sunil Mani. 2012. "Foreign R&D Centres in India: An Analysis of Their Size, Structure and Implications." Working Paper No. 2012-01-06. Indian Institute of Management - Ahmedabad.

Beckley, Michael. 2012. "China's Century? Why America's Edge Will Endure." *International Security* 36 (3): 41–78.

Bound, Kirsten. 2008. *Brazil: The Natural Knowledge Economy*. London: Demos.

Brandt, Loren, and Thomas G. Rawski. 2008. *China's Great Economic Transformation*. Cambridge: Cambridge University Press.

Branstetter, Lee, Guangwei Li, and Francisco Veloso. 2014. "The Rise of International Co-Invention." Unpublished manuscript. National Bureau of Economic Research. http://www.nber.org/authors/lee_branstetter.

Breznitz, Dan. 2007. *Innovation and the State*. New Haven, Conn.: Yale University Press.

Breznitz, Dan, and Michael Murphree. 2011. *Run of the Red Queen: Government, Innovation, Globalization, and Economic Growth in China*. New Haven, Conn.: Yale University Press.

Cao, Cong, Richard P. Suttmeier, and Denis Fred Simon. 2006. "China's 15-Year Science and Technology Plan." *Physics Today*, December.

Chaudhuri, Anindya. 2012. "Creeping Tiger, Soaring Dragon: India, China and Competition in Information Technologies." *China & World Economy* 20 (6): 1–28.

Chen, Ling, and Barry Naughton. 2013. "The Emergence of Chinese Techno-Industrial Policy: From Mega Projects to Strategic Emerging Industries, 2003-2011." Institute for Brazil-China Studies. http://www.ibrach.org/china-observatory-areas-research.

China Daily. 2014. "High Quantity, Low Quality: China's Patent Boom," June 23. http://www.chinadaily.com.cn/business/2014-06/23/content_17609675.htm.

China State Statistical Bureau. 2007. *Zhongguo Keji Tongji Nianjian 2007 [China Statistical Yearbook on Science and Technology 2007]*. Berkeley: Zhongguo Tongji Chubanshe.

———. 2011. *Zhongguo Keji Tongji Nianjian 2011 [China Statistical Yearbook on Science and Technology 2011]*. Beijing: Zhongguo Tongji Chubanshe.

———. 2013. *Zhongguo Keji Tongji Nianjian 2013 [China Statistical Yearbook on Science and Technology 2013]*. Beijing: Zhongguo Tongji Chubanshe.

Cornell University, INSEAD, and WIPO. 2014. *The Global Innovation Index 2014*. Geneva: WIPO. https://www.globalinnovationindex.org/content.aspx?page=GII-Home.

Dahlman, Carl J. 2010. "Innovation Strategies in Brazil, China and India: From Imitation to Deepening Technological Capability in the South." In *The Rise of Technological Power in the South*, edited by Xiaolan Fu and Luc Soete, 15–48. Basingstoke, UK: Palgrave MacMillan.

Dahlman, Carl J., and Thomas Andersson. 2000. *Korea and the Knowledge Economy: Making the Transition*. Paris: OECD and World Bank Institute.

de Brito Cruz, Carlos H., and Luiz de Mello. 2006. "Boosting Innovation Performance in Brazil." In *OECD Economics Department Working Papers, No. 532*. OECD Publishing. doi:http://dx.doi.org/10.1787/357276015553.

Deiaco, Enrico, and Carl Jeding. 2015. "To Boldly Go... Characteristics of China's Innovation Policy." In *Innovation Spaces in Asia: Entrepreneurs, Multinational Enterprises and Policy*, edited by Maureen McKelvey and Sharmistha Bagchi-Sen. Cheltenham, UK: Edward Elgar.

Di Minin, Alberto, Jieyin Zhang, and Peter Gammeltoft. 2012. "Chinese Foreign Direct Investment in R&D in Europe: A New Model of R&D Internationalization?" *European Management Journal* 30 (3): 189–203. doi:10.1016/j.emj.2012.03.004.

Drezner, Daniel. 2001. "State Structure, Technological Leadership and the Maintenance of Hegemony." *Review of International Studies* 27 (01): 3–25.

Ernst, Dieter. 2006. "Innovation Offshoring: Exploring Asia's Emerging Role in Global Innovation Networks." *East-West Center Special Reports*, no. 10 (July).

———. 2009. *A New Geography of Knowledge in the Electronics Industry? Asia's Role in Global Innovation Networks*. Honolulu: East-West Center.

———. 2014. *Upgrading India's Electronics Manufacturing Industry: Regulatory Reform and Industrial Policy*. Honolulu: East-West Center.

European Commission. 2013. "The 2013 EU R&D Scoreboard." *Economics of Industrial Research and Innovation*. http://iri.jrc.ec.europa.eu/scoreboard13.html.

Eurostat. 2015. "Direct Investment Inward Flows by Main Investing Country." *Balance of Payments Database: European Union Direct Investments*. http://ec.europa.eu/eurostat/web/balance-of-payments/data/main-tables.

Federation of Indian Chambers of Commerce and Industry. 2014. "FICCI's Recommendations for the Science, Technology & Innovation Sector." In . New Delhi. http://www.ficci.com/sector-policy-recommendations.asp?secid=35.

Feigenbaum, Evan. 2003. *China's Techno-Warriors: National Security and Strategic Competition from the Nuclear to the Information Age*. 1st ed. Stanford, Calif.: Stanford University Press.

Fong, Glenn R. 1998. "Follower at the Frontier: International Competition and Japanese Industrial Policy." *International Studies Quarterly* 42 (2): 339–66.

Fuller, Douglas B. 2014. "Chip Design in China and India: Multinationals, Industry Structure and Development Outcomes in the Integrated Circuit Industry." *Technological Forecasting and Social Change* 81 (January): 1–10. doi:10.1016/j.techfore.2012.10.025.

Fu, Xiaolan. 2015. *China's Path to Innovation*. Cambridge: Cambridge University Press.

Fu, Xiaolan, and Yundan Gong. 2011. "Indigenous and Foreign Innovation Efforts and Drivers of Technological Upgrading: Evidence from China." *World Development* 39 (7): 1213–25.

Gao, Jian, and Gary H. Jefferson. 2007. "Science and Technology Take-off in China? Sources of Rising R&D Intensity." *Asia Pacific Business Review* 13 (3): 357–71. doi:10.1080/13602380701291933.

Gao, Yuan. 2015. "Ministry Unveils Blueprint to Boost Manufacturing." *China Daily*. Accessed May 25. http://www.chinadaily.com.cn/business/2015-05/20/content_20766997.htm.

Gerschenkron, Alexander. 1962. *Economic Backwardness in Historical Perspective*. Cambridge, Mass.: Harvard University Press.

Government of India. 2013a. "Science, Technology and Innovation Policy 2013." http://www.dst.gov.in/sti-policy-eng.pdf.

———. 2013b. "M. Phil and Doctorate Degrees Awarded Faculty-Wise (1990-91 to 2010-11)." *Department of Science and Technology, Research and Development Statistics, 2011-2012*. September. http://www.nstmis-dst.org/SnT-Indicators2011-12.aspx.

———. 2014a. *Office of the Controller General of Patents, Designs, Trade Marks and Geographical Indication Annual Report 2012-2013*. Delhi: Government of India.

———. 2014b. "Dr Harsh Vardhan Says Vision S&T 2020 on Cards." *Press Information Bureau*. November 17. http://pib.nic.in/newsite/PrintRelease.aspx?relid=111488.

Hobday, Michael. 2000. "East versus Southeast Asian Innovation Systems: Comparing OME- and TNC-Led Growth in Electronics." In *Technology, Learning, and Innovation*, edited by Linsu Kim and Richard R. Nelson, 129–69. Cambridge, UK: Cambridge University Press.

Hobday, Michael, Howard Rush, and John Bessant. 2004. "Approaching the Innovation Frontier in Korea: The Transition Phase to Leadership." *Research Policy* 33 (10): 1433–57.

Hu, Albert. 2014. "China's R&D Intensification and the Role of the State." In *China's Evolving Industrial Policies and Economic Restructuring*, edited by Sarah Y. Tong and Yongnian Zheng, 74–86. New York: Routledge.
Huawei. 2014. "Research & Development - About Huawei." http://www.huawei.com/en/about-huawei/corporate-info/research-development/index.htm.
IMF. 2014. "World Economic Outlook: October 2014 Edition." http://www.imf.org/external/pubs/ft/weo/2014/02/weodata/index.aspx.
Infosys. 2014a. "Infosys Annual Report 2013-2014." http://www.infosys.com/investors/reports-filings/annual-report/.
———. 2014b. "Overview." *Infosys Labs*. http://www.infosys.com/infosys-labs/.
Johnson, Chalmers. 1982. *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925-1975*. Stanford, Calif.: Stanford University Press.
Kale, Dinar, and Steve Little. 2007. "From Imitation to Innovation: The Evolution of R&D Capabilities and Learning Processes in the Indian Pharmaceutical Industry." *Technology Analysis & Strategic Management* 19 (5): 589–609. doi:10.1080/09537320701521317.
Kennedy, Andrew B. 2012. *The International Ambitions of Mao and Nehru: National Efficacy Beliefs and the Making of Foreign Policy*. Cambridge University Press.
———. 2013. "China's Search for Renewable Energy: Pragmatic Techno-Nationalism." *Asian Survey* 53 (5): 909–30.
———. 2015. "Powerhouses or Pretenders? Debating China's and India's Emergence as Technological Powers." *The Pacific Review* 28 (2): 281–302.
Kim, Linsu. 1997. *Imitation to Innovation: The Dynamics of Korea's Technological Learning*. Cambridge, Mass.: Harvard Business Press.
Kim, Sung-Young. 2012. "Transitioning from Fast-Follower to Innovator: The Institutional Foundations of the Korean Telecommunications Sector." *Review of International Political Economy* 19 (1): 140–68. doi:10.1080/09692290.2010.503125.
King, Christopher, and David Pendlebury. 2013. *Research Fronts 2013: 100 Top-Ranked Specialties in the Sciences and Social Sciences*. Thomson Reuters.
Krishnan, Rishikesha T. 2010. *From Jugaad to Systematic Innovation: The Challenge for India*. Bangalore: Utpreraka Foundation.
Liang, Mark. 2012. "Chinese Patent Quality: Running the Numbers and Possible Remedies." *The John Marshall Review of Intellectual Property Law* 11: 478–522.
Liu, Xielin, and Peng Cheng. 2011. "Is China's Indigenous Innovation Strategy Compatible with Globalization?" Policy Studies 61. Honolulu: East-West Center.
Li, Zheng. 2011. *Zhongyang Qiye Jishu Chuangxin Baogao 2011 {Report on Technological Innovation of Central State-Owned Enterprises 2011]*. Beijing: Zhongguo Jingji.
Lo, Joy Ann. 2014. Senior Communications Manager, Microsoft, personal interview by author, February 19.

Mahmood, Ishtiaq P., and Carlos Rufin. 2005. "Government's Dilemma: The Role of Government in Imitation and Innovation." *Academy of Management Review* 30 (2): 338–60.
Mandiant. 2013. "APT1: Exposing One of China's Cyber Espionage Units." http://intelreport.mandiant.com.
Marin, Anabel, and Subash Sasidharan. 2010. "Heterogeneous MNC Subsidiaries and Technological Spillovers: Explaining Positive and Negative Effects in India." *Research Policy* 39 (9): 1227–41.
Ministry of Science and Technology of the People's Republic of China. 2011. "Guojia Daxue Kejiyuan Shierwu Fazhan Guihua Gangyao Jiesdu [An Explanation of the Twelfth Five Year Plan's Program for Developing National University Science and Technology Parks]." August 19. http://www.most.gov.cn/kjzc/zdkjzcjd/201108/t20110819_89134.htm.
Mokyr, Joel. 1990. *The Lever of Riches: Technological Creativity and Economic Progress*. New York: Oxford University Press.
Murphy, Colum, and Lilian Lin. 2014. "For China's Jobseekers, Multinational Companies Lose Their Magic." *The Wall Street Journal*, April 3. http://blogs.wsj.com/chinarealtime/2014/04/03/for-chinas-jobseekers-multinational-companies-lose-their-magic/?mod=chinablog.
Nahm, Jonas, and Edward Steinfeld. 2014. "Scale-up Nation: China's Specialization in Innovative Manufacturing." *World Development* 54: 288–300.
Naughton, Barry. 2011. "China's Economic Policy Today: The New State Activism." *Eurasian Geography and Economics* 52 (3): 313–29.
———. 2012. "SASAC in the Age of Technology: Mandates, Missions, and Results." In *Conference on the Structure, Process, and Leadership of the Chinese Science and Technology System*. University of California, San Diego.
OECD. 2009. *OECD Reviews of Innovation Policy: Korea 2009*. Paris: Organisation for Economic Co-operation and Development.
———. 2015. "Percentage of GERD Financed by Industry." *Main Science and Technology Indicators*. http://stats.oecd.org/Index.aspx?QueryId=33210.
Olson, Mancur. 2008. *The Rise and Decline of Nations: Economic Growth, Stagflation, and Social Rigidities*. New Haven, Conn.: Yale University Press.
Pulakkat, Hari. 2015. "Can PM Narendra Modi Work His Magic on Indian Science?" *The Economic Times*, January 14.
Qiu, Jane. 2014. "China Goes back to Basics on Research Funding." *Nature* 507 (March): 148–49.
Quan, Xiaohong. 2010. "Knowledge Diffusion from MNC R&D Labs in Developing Countries: Evidence from Interaction between MNC R&D Labs and Local Universities in Beijing." *International Journal of Technology Management* 51 (2): 364–86.
Rao, Yi, Lu Bai, and Chen-Lu Tsou. 2004. "Zhongguo Keji Xuyao de Genben Zhuanbian: Cong Chuantong Renzhi Dao Jingzheng Yousheng Tizhi [The Fundamental Transformation Needed in Chinese Science and Technology: From Traditional Rule-by-Man to Rule-by-Merit]." *Nature* 432 (supplement) (November): A12–17.

Rosen, Daniel H., and Thilo Hanemann. 2012. "Chinese Direct Investment in California." San Francisco: The Asia Society.
Samuels, Richard J. 1994. *"Rich Nation, Strong Army": National Security and the Technological Transformation of Japan*. Ithaca, NY: Cornell University Press.
Schwaag-Serger, Sylvia. 2009. "Foreign Corporate R&D in China: Trends and Policy Issues." In *The New Asian Innovation Dynamics: China and India in Perspective*, edited by Govindan Parayil and Anthony P. D'Costa, 50–78. New York: Palgrave MacMillan.
Shalal, Andrea. 2015. "Top U.S. Spy Says Skeptical about U.S.-China Cyber Agreement." *Reuters*, September 30. http://in.reuters.com/article/2015/09/29/usa-cybersecurity-idINL1N11Z16D20150929.
Shi, Yigong, and Yi Rao. 2010. "China's Research Culture." *Science* 329 (5996): 1128. doi:10.1126/science.1196916.
Srivastava, Anurag. 2014. Wipro Chief Technology Officer, personal interview by author, Bangalore, India, January 17.
State Council of the People's Republic of China. 2006. "Guojia Zhongchangqi Kexue He Jishu Fazhan Guihua Gangyao (2006-2020 Nian) [National Medium- and Long-Term Program for Science and Technology Development (2006-2020)]." http://www.gov.cn/jrzg/2006-02/09/content_183787.htm.
———. 2010. "Guowuyuan Guanyu Jiakuai Peiyu He Fazhan Zhanluexing Xinxing Chanye de Jueding [State Council Decision on Accelerating the Cultivation and Development of Strategic Emerging Industries]." http://www.gov.cn/zwgk/2010-10/18/content_1724848.htm.
———. 2015. "Guowuyuan Guanyu Yinfa 'Zhongguo Zhizao 2025' de Tongzh [State Council Issues Notice on 'Made in China 2025']." May 8. http://www.gov.cn/zhengce/content/2015-05/19/content_9784.htm.
Subramanian, Raghavan. 2014. Associate Vice President for Emerging Technologies at Infosys, personal interview by author, Bangalore, India January 17.
The Economic Times. 2014. "Cisco Systems to Increase Commitments to India, Especially in Inclusion: John Chambers." Accessed January 14. http://articles.economictimes.indiatimes.com/2013-04-18/news/38647188_1_ceo-john-chambers-globalization-centre-east-cisco.
The Economist. 2010. "Patents, Yes; Ideas, Maybe," October 14. http://www.economist.com/node/17257940.
Thomson Reuters. 2015. "SDC Platinum Database." subscription only.
UNESCO. 2014. "Science, Technology and Innovation Data." *UIS.Stat*. http://data.uis.unesco.org.
United States Office of The National Counterintelligence Executive. 2011. "Foreign Spies Stealing US Economic Secrets in Cyberspace: Report to Congress on Foreign Economic Collection and Industrial Espionage, 2009-2011." http://www.ncix.gov/publications/reports/fecie_all/Foreign_Economic_Collection_ 2011.pdf.
U.S. Bureau of Economic Analysis. 2014a. "Foreign Direct Investment in the U.S., Majority-Owned Bank and Nonbank U.S. Affiliates, Research and Development Expenditures, 2007-2011." *International Data: Direct*

Investment and Multinational Enterprises. http://www.bea.gov/iTable/index_MNC.cfm.

———. 2014b. “Table II.H 6. Research and Development Performed by Affiliates, Industry of Affiliate by Country of UBO, Revised Estimates for 2011.” *Foreign Direct Investment in the United States: Financial and Operating Data for U.S. Affiliates of Foreign Multinational Companies*. http://www.bea.gov/international/fdius2011_preliminary.htm.

———. 2014c. “Table II.I 3. Research and Development Performed by Affiliates, Country by Industry, Preliminary 2012 Statistics.” *U.S. Direct Investment Abroad: Financial and Operating Data for U.S. Multinational Companies*. http://www.bea.gov/international/usdia2011p.htm.

U.S. National Science Foundation. 2014. *Science and Engineering Indicators 2014*. Arlington, VA: National Science Foundation.

U.S. Patent and Trademark Office. 2014. “Patent Full-Text Databases.” http://appft.uspto.gov/netahtml/PTO/index.html.

Wade, Robert. 1990. *Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization*. Princeton: Princeton University Press.

Wipro. 2013. “Wipro Annual Report 2012-2013.” http://www.wipro.com/investors/annual-reports.aspx.

Wong, Joseph. 2011. *Betting on Biotech: Innovation and the Limits of Asia’s Developmental State*. New York: Cornell University Press.

World Bank. 2007. *Unleashing India’s Innovation: Toward Sustainable and Inclusive Growth*. Washington, DC: The World Bank.

———. 2015. “Data.” http://data.worldbank.org/.

World Trade Organization. 2014. *Trade Policy Review: China*. http://www.wto.org/english/tratop_e/tpr_e/tpr_e.htm.

Xinhua. 2014. “China Eyes Quality Patents Amid Application Surge.” *People’s Daily Online*, April 22. http://english.people.com.cn/business/8606364.html.

Yeung, Henry Wai-chung. 2014. “Governing the Market in a Globalizing Era: Developmental States, Global Production Networks and Inter-Firm Dynamics in East Asia.” *Review of International Political Economy* 21 (1): 70–101. doi:10.1080/09692290.2012.756415.

Zinnov. 2013. “Crossing the Value Chasm.” November. www.zinnov.com.