Powerhouses or Pretenders?

Debating China and India's Emergence as Technological Powers

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Abstract: Are China and India emerging as technological powerhouses in the 21st century? This essay reviews the interdisciplinary debate that has been inspired by this question in recent years. It begins by considering recent studies that are relatively impressed with China and India's recent accomplishments and potential in this regard. Next, it reviews works that are less impressed with their track records and prospects. It then considers a series of more equivocal studies that remain more or less undecided about China and India's technological trajectories. The final section evaluates the debate as a whole and proposes new directions for scholarship in this field.

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Technological creativity represents a key source of national power, a point long recognized by international relations scholars. New technologies not only spur economic growth and national prosperity, but can also provide states with leverage in international trade. New technologies from railroads to nuclear energy have also generated new sources of military power, at least for states that can surmount the financial and organizational hurdles to military innovation (Horowitz 2010). Moreover, nations vary widely in their innovative capacities. Long cycle theorists, who have probed the connections between technology and national power with particular care, note that technological development at a given point in history tends to cluster in a single national economy, from which it diffuses throughout the international system (Thompson 1990; Modelski and Thompson 1996).

In this context, it is not surprising that technological innovation should be a pressing preoccupation for rising powers. To be sure, a rising state may simply be a "fast follower," rapidly adopting new technologies invented elsewhere rather than creating them on its own. When the hurdles to imitation are high, however, the advantages of possessing a new technology first – both in the economic and military spheres – can be considerable (Milner and Yoffie 1989; Mueller 1997; Horowitz 2010). Indeed, the historical record makes clear that technological innovation often helps fuel the rise of new powers. Germany rose to economic prominence in the late 19th century as it "institutionalized innovation" in what David Landes calls "the second wind" of the industrial revolution (Landes 2003, 352). The rise of the United States in the early and mid-20th century was not simply a function of its increasingly vast economy, but also technological leadership in areas ranging from electric light to mass production to air

transport (Gordon 2004, 23–34). Following World War II, Japan's remarkable rise in automotive and information technology led to predictions that it would eclipse the U.S. as the world's leading economy, expectations that have faded as Japan has struggled to keep up in the age of the Internet (Drezner 2001).

Today's rising powers - China and India in particular – are certainly not content to rely on the outside world for new technologies. In 2006, China's National Medium- and Long-Term Program for Science and Technology Development (2006-2020), or MLP, was launched to rapidly advance "indigenous innovation" and to promote 16 "megaprojects" in particular (State Council 2006).[1] The MLP was spurred in part by dissatisfaction with China's role in the world economy, as well as a conviction that foreign companies would no longer transfer technologies, particularly advanced technologies, to Chinese firms (Cao, Suttmeier, and Simon 2006, 41). The document itself argued that "in areas critical to the national economy and security, core technologies cannot be purchased" and that China should "take the initiative in the fierce international competition." Yet the MLP hardly endorsed autarky: the document listed a range of shortcomings in China's own science and technology system and concluded that international cooperation would be essential for China going forward. In 2010, China added a follow-on plan to speed the development of seven "Strategic Emerging Industries" – an effort to place Chinese companies at the forefront of technological innovation.[2] While more targeted than the MLP, this initiative also represents a striking mix of technological ambition, nationalist anxiety, and international outreach.

India has its own ambitions. While lacking plans as detailed and dirigiste as the MLP, Prime Minister Manmohan Singh unveiled a new national Science, Technology,

and Innovation (STI) Policy in early 2013 (Government of India 2013). While the new policy sounded more relaxed about international competition than China's MLP, there is no little anxiety in India about falling behind other countries – particularly as China raises its technological ambitions (Krishna 2013). Indeed, Singh lamented in 2012 that India's position in "the world of science" had been declining for decades (India Today Online 2012). In response, the new STI policy aspires to place India "among the top five global scientific powers" by 2020. Toward this end, the policy called for doubling the country's research and development (R&D) spending to 2 percent of GDP – a longstanding goal of Singh's government – over five years, through a mix of public-private partnerships and greater private investment. It also called for quadrupling India's share of articles in elite scientific journals, from 2.5 percent to 10 percent, and raising the participation of women in STI activities. The policy also stated that "around 10 sectors of high impact potential" would be chosen for "directed STI intervention and deployment of requisite resources." While it remains to be seen how these various goals will be pursued, it is clear that India is looking to raise its profile in the world of science and technology.

If China and India are preoccupied with improving their technological creativity, the question remains how successful they have been in this regard in recent years, as well as what we should expect of them in the future. In recent years, a diverse array of scholars has taken up these questions with great interest. The result has been a fascinating interdisciplinary debate, but no clear consensus has emerged. As described below, some scholars are impressed with China and India's track records and offer positive assessments of their future prospects. Others are decidedly critical and downplay the potential of these states to become innovation powerhouses. A third group

of scholars offers more ambiguous assessments and remains essentially undecided about the future.

To shed more light on this question, this essay reviews the ongoing debate over China and India's emergence as technological powers. The goal here is not to decide who is "winning" the debate, which will undoubtedly continue for years to come. Instead, my purpose is to explore the various arguments and to suggest new directions for the literature in the future. The essay begins by considering recent studies that are relatively impressed with China and India's recent accomplishments and potential in technological innovation. Next, it reviews works that are relatively unimpressed. It then considers a range of more equivocal studies that have explored China and India's strengths and weaknesses, and that remain more or less undecided about the future. The final section evaluates the debate as a whole and proposes some new directions for scholarship in this field.

The Impressed

As China and India have recorded remarkable economic progress over the past few decades, a number of scholars have been impressed by their emergence as technological powers as well. There is considerable diversity within this group, and it would be inaccurate to suggest that they share the same conception of "innovation" and what drives it. Nonetheless, there are some underlying themes in these writings. First, they tend to be less theoretical and more empirical. More precisely, they tend to be concerned with documenting China and India's progress in terms of relatively traditional indicators of innovation, such as scientific publications, national expenditure on R&D,

and patent data. Second, some (if not all) of these writers suggest that the shift to greater innovation in China and India is a natural result of economic development – and even inevitable. Third, and most universally, these writings are not only impressed with China and India's track records to date but also optimistic about their future prospects.

To begin, Carl Dahlman contends that innovation in China and India should be understood to include not just knowledge that is new to the world, but also knowledge that is new to these countries (Dahlman 2010; Dahlman 2007). That is, he is not simply concerned with whether China and India are making advances at the technological frontier, but with the process of technological modernization within these countries more broadly. Dahlman's approach is systematic: he assesses efforts to acquire foreign technology (through inward FDI and technology licensing); efforts to develop domestic technologies (through education and R&D spending); and efforts to diffuse technology domestically (by examining penetration rates of personal computers, for example) (Dahlman 2010). Comparing China with India as well as Brazil, Dahlman concludes that China has been more successful than the other two in all three respects. Yet he seems impressed with the track record of all three countries when it comes to innovation (as he defines it); Dahlman writes that "all three countries have made major technological innovations" (34). His conclusion is particularly optimistic about both China and India, suggesting that both of the Asian giants "are well on their way to becoming major technological powers" (44).

Like Dahlman, Ernest Preeg considers technological development in broad terms and comes away impressed with both China and India. As early as 2008, he characterized China as a "fully engaged technology superstate" (Preeg 2008, 11). India, meanwhile,

was five to ten years behind China, but nonetheless "clearly an emerging advanced technology superstate." While the meaning of these terms remains murky throughout his text, the empirical investigation is quite broad: Preeg considers technology policy, R&D spending, technical education, foreign direct investment, the composition of national trade, the innovation of domestic enterprises, patent data, and academic publications.[3] The analysis does not always support the rather dramatic conclusion, however. Preeg notes that there are "major weaknesses" (41) in university education in both China and India, for example. He argues that innovation in information technology and telecommunications is "lifting China and India toward advanced technology superstate status," but suggests that this process remains poorly understood and that the relative importance of domestic and foreign firms in it remains unclear (102). Looking ahead, Preeg characterizes China's drive for indigenous innovation as a "high-risk" (29) strategy, given the role of foreign firms in China's development.

Recent writings touting the rise of "Chindia" have emphasized that China and India's emergence as centers of innovation is natural and even inevitable. In *Chindia Rising*, Jagdish Sheth writes that "the journey of industrialization inevitably leads up the value chain" and foresees "an advancing wave of Chindian innovation" (Sheth 2008, 75). He not only cites the potential for educational reforms in China and India to produce millions of talented technicians and engineers, he also suggests that Chindia is emerging as "the world's R&D capital" (79). Peter Engardio's *Chindia* is more circumspect, but he also sees China and India's emergence as technology powers as inevitable. "It is only a matter of time," he writes, "before India and China are at the forefront in technological innovation" (Engardio 2007, 169). Engardio concedes that problems such as intellectual

property protection will hold them back in the near-term, but he stresses that both countries boast growing numbers of science and engineering graduates, rising R&D expenditures, and deepening ties with technology companies and universities abroad.

Some writers are impressed with China in particular. Hu Angang's *China in 2020* is a case in point (Hu 2011). Like the "Chindia" scholars, Hu sees China's emergence as a technology power as inevitable, thanks to its rapid economic growth, though he also stresses the role of globalization and government policy. In fact, his assessment is not only strikingly optimistic, but also remarkably precise. Hu decomposes what he calls national "S&T power" into five national capacities, each of which has a quantitative indicator:

1) Capacity for innovation in science (number of papers published in international scientific journals);
2) Capacity for innovation in technology (invention patent applications filed by residents with national patent office);
3) Capacity to use new technologies (number of people using computers within the country);
4) Capacity to use global information (number of people with Internet access within the country);
5) Capacity for R&D (R&D expenditures in purchasing power parity terms).

Taking these measures together, Hu concludes that China is already a "strong innovative power" (95), with 9.7 percent of the world's S&T power as of 2007, compared to 14.6 percent for Japan and 23.2 percent for the US (110). Hu adds that China's performance

makes clear that it will overtake these two countries to become "the world's largest S&T power" (110). Notably, India does not figure as an S&T power of consequence in Hu's assessment.

A few impressed scholars defy the general trend in the "impressed" literature and focus on less obvious indicators of innovation. Nirmalya Kumar and Phanish Puranam, for example, contend that much of the innovation that occurs within India is "invisible" and that the country is underrated as a technology power as a result (Kumar and Puranam 2012). With MNCs segmenting innovation into a range of tasks conducted in multiple locales across the globe, as well as outsourcing some activities to other firms, India has taken advantage. MNCs have set up hundreds of captive R&D units in India, as well as outsourcing IT work to firms like Infosys and Wipro, thereby taking advantage of India's pool of educated but inexpensive labor. The result is that Indian knowledge workers play a role in creating many new products, but the patents and products are identified with the western multinationals rather than the Indian labor that developed them.

Notably, the potential for industrial espionage has not featured prominently in the writings of impressed scholars. In a sense, this is not surprising: most of the above studies were completed before allegations of Chinese espionage began to receive sustained attention in the media. Still, these allegations are certainly fueling concern that western technological secrets are being siphoned off with frightening speed. 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). In 2012, James Alexander, the Director of the U.S. National Security Agency, said that cyber-espionage

was leading to "the greatest transfer of wealth in history" ("Chinese Hackers Steal Everything" 2012). As noted below, however, not all observers agree that industrial espionage is having such a dramatic impact.

In short, a number of scholars are impressed with the pace with which China and India are emerging as technological powers. As noted above, while there is considerable diversity in this literature, there are also several underlying themes. There is a clear tendency to focus on relatively traditional, quantitative indicators of technological progress, such as national R&D spending and patent data, rather than underlying institutions or processes. In addition, some impressed scholars see innovation as an inevitable outgrowth of China and India's rapid economic development. Most fundamentally, they all share a conviction that China and India have made considerable progress to date, and that their prospects in this realm are bright.

The Unimpressed

Notwithstanding China and India's rapid economic growth in recent decades, some scholars remain decidedly unimpressed with their technological trajectories. Whether explicit or implicit, a key theme in this literature is the deficiencies in China and India's technology policies or their "national innovation systems" more broadly. The latter refers to the set of relationships between government, academic, and private actors that undergird the creation and diffusion of new technologies (Nelson 1993; Organization for Economic Cooperation and Development 1997). In this view, innovative capacity is does not arise easily and is not an inevitable product of development; it rests on a complex web of social and economic ties that must be nurtured and sustained over time.

Accordingly, many of these scholars are more concerned with relationships, mindsets, and incentives than with more readily quantified indicators of innovation. When these scholars do consider quantitative evidence, they typically critique the quality of the data emerging from these Asian giants, and they also note the need to consider absolute differences between countries as well as growth rates.

To begin, critics of China's innovation system make a number of points. In 2004, George Gilboy cited a range of constraints on China's innovative capacity, including low corporate spending on R&D as a percentage of revenue, a failure to invest in indigenizing imported technologies, and a lack of industrial collaboration and horizontal networking, among others (Gilboy 2004, 42–46). In 2008, the OECD produced its own, fairly critical, assessment of China's national innovation system. It noted that while China was making concerted investments in R&D and human capital, the enterprise system remained weak and "a proportionate increase in innovation performance" had yet to take place (OECD 2008, 17). In 2012, Michael Beckley described China as mired in "technological stagnation" and listed a wide range of shortcomings in its national innovation system and performance (Beckley 2012, 69). Among other things, Beckley highlighted misconduct in scientific research, the reluctance of Chinese companies to invest in R&D and new products, and the country's reliance on foreign companies. As Beckley concluded, "a comparison of U.S. and Chinese innovation systems over the past twenty years provides strong evidence against declinism and in favor of the alternative perspective that China continues to lag behind the United States" (72).

Criticisms of China's innovative capacity are certainly not limited to foreigners; knowledgeable Chinese scholars have also raised concerns. Zhao Zhiyun and Yang

Chaofeng, for example, are scholars at the Institute of Scientific and Technical Information of China (ISTIC), a research institute under the Ministry of Science and Technology. They maintain that while technology imports have contributed substantially to China's growing total factor productivity from 1979 to 2009, China's own R&D spending has contributed quite little in this regard (Zhao and Yang 2011). In a separate study, Yang and Zhao argue that the productivity of China's R&D spending is far below that of developed countries (Yang and Zhao 2009). Zhao and Du Hongliang (also of ISTIC), meanwhile, have also explored the international influence of China's science and technology (Du and Zhao 2010). While noting some successes, they also list a range of constraints that hold China back, including a preoccupation with economic growth rather than education, a deficiency of innovative talent, and the policies of some developed countries.

Critics of India's innovation system are readily found as well. Rishikesha Krishnan of the India Institute of Management in Bangalore asks why India, with so many individually talented people, has failed to live up to its "innovation potential" (Krishnan 2010). Among other things, he highlights the lack of innovation inputs: inadequate public and private funding, limited management capacity in many enterprises, and the failure of the university system to undertake cutting-edge research or provide sufficient numbers of well-trained knowledge workers. Krishnan also points to social and cultural barriers to innovation in India. These include poor teamwork, a relaxed attitude toward deadlines, a lack of confidence in innovation capabilities, excessively hierarchical organizations, and a low tolerance for failure. V.V. Krishna of Jawaharlal Nehru University also worries that India is not living up to its potential. He cites a lack

of government commitment to R&D, inadequate links between different types of organizations, and "official neglect" of the country's universities (Krishna 2013). Focusing on information and telecommunications technologies (ITT) in particular, Anindya Chaudhuri sees India as lagging far behind the US and increasingly behind China as well (Chaudhuri 2012). He suggests that the Indian government makes too little effort to ensure that the R&D activities conducted by foreign firms in India generate positive spillovers for the country more generally. He also laments that Indian software firms generate little intellectual property of their own, focus on businesses rather than consumers, and are too reliant on the US market.

There is also concern with specific Chinese and Indian initiatives and policies – or the lack thereof. For China, the concern is excessive state activism. Following the release of the MLP in 2006, Sylvia Serger and Magnus Breidne wrote that the plan assumed that innovation could be "decreed from above" (Serger and Breidne 2007, 161). They noted that it was written "by and for civil servants" and worried that too little attention had been paid to entrepreneurs, customers, and the market (157). Following the release of the SEI, Barry Naughton outlined additional concerns with what he called the "protectionist elements" in China's approach (Naughton 2011, 326). These include the danger that protectionist policies will become increasingly costly and difficult to undo over time and that they will alienate important economic partners. Naughton also warned that state intervention to "pick winners" at the technological frontier will prove much more difficult and costly for China than was the case when the goal was simply technological catch-up in established industries (327). With regard to China's industrial espionage, some are doubtful that it does the country much good. James Lewis suggests

that cyber-theft costs the United States "no more than $100 billion a year and perhaps much less" — what he called "a rounding error in our $15 trillion economy" (Lewis 2013). Lewis adds that China probably lacks the technical skills and industrial base in some high-tech areas to turn stolen intellectual property into competitive advantage.

On the Indian side, the opposite critique has been made: the state is not too active, but too timid. Ramaseshan Ramachandran writes that the Indian state has repeatedly devised plans to strengthen its science and technology base, but laments that it has never supported these plans with economic measures (Ramachandran 2002). Krishnan writes that the Indian government has failed to support industrial innovation in the reform era for several reasons – perhaps most basically because Indian leaders, such as Manmohan Singh, are ideologically averse to state intervention in the economy (Krishnan 2010, 130–31). Krishnan calls for a more flexible mindset and a raft of new measures, including an expansion and reorganization of public support for technology development and commercialization. More recently, V.V. Krishna has criticized India's new Science, Technology, and Innovation Policy as "high on goals" but "low on commitment" (Krishna 2013). In Krishna's view, stronger efforts must be made to boost national R&D and to strengthen the national university system.

Lastly, while critics often focus on China and India's innovation systems or policies, it is not the case that they simply ignore traditional quantitative indicators of innovation activity. Instead, there are at least two lines of critique in this regard. First, some dismiss some of the more impressive figures emerging from these Asian giants as misleading. Xuan Li and Yogesh Pai, for example, note that Chinese patent data give a distorted picture of innovation in the country (Li and Pai 2010, 73). In particular, they

note that patents by domestic residents in China include those of joint ventures and wholly foreign-owned enterprises, which are treated as domestic enterprises for purposes of Chinese law. Second, critics tend to focus less on growth rates and more on absolute differences between "rising" states and developed countries. Vincent Shie and Craig Meer, for example, compare China, India, South Korea, and Taiwan with the U.S. and Japan in this regard (Shie and Meer 2010). Focusing on R&D spending, patent applications, and invention patents granted in the U.S., the authors conclude that the United States and Japan retain formidable leads, notwithstanding rapid growth in the developing countries. A follow-on study comparing China with the U.S. and Japan by Shie, Meer, and Nian-Feng Shin also finds persistent absolute differences (Shie, Meer, and Shin 2012). Focusing on the U.S. and China in particular, Sheena Chestnut and Iain Johnston, as well as Michael Beckley, reach similar conclusions (Chestnut and Johnston 2009, 246–48; Beckley 2012, 69–71).

To sum up, a significant contingent of scholars remain unimpressed with China and India's ascents as technological powers. These critics tend to highlight shortcomings in the national innovation systems of these two countries, with problems ranging from academic research to corporate behavior to university systems. Critics also fault specific initiatives and policies in both countries, with the Chinese government criticized as excessively interventionist and the Indian government charged with being insufficiently supportive. While these critics are frequently concerned with Chinese and Indian institutions, they do not disregard quantitative indicators. Instead, they often critique the data emerging from these Asian giants as misleading, and they also note the need to consider absolute differences between countries as well as growth rates.

The Undecided

A third group of scholars is hard to classify as "unimpressed" or "impressed." Like the unimpressed scholars, this group tends to look beyond the standard indicators of innovation performance. Unlike the unimpressed scholars, however, this group sees the evidence as highly ambiguous. Whereas unimpressed scholars see China and India's innovation systems as beset with problems, this group includes scholars who see improvement in some areas – and even strengths – even as many problems remain. Others are more concerned with other types of relationships and processes, such as the globalization of innovation, but still come away with equivocal conclusions. These scholars thus tend to be highly uncertain about what the future holds – and are best classified as "undecided."

As suggested above, there are several distinct sub-themes in this literature. First, some scholars in this group focus their attention on innovation systems and processes. Distinguishing between the tangible and intangible ingredients of technological innovation, they tend to laud China or India's capabilities with respect the former, while expressing concern about the latter (Bound 2007; Wilsdon and Keeley 2007; Cao, Simon, and Suttmeier 2009; Segal 2011). Cong Cao, Denis Simon, and Richard Suttmeier, for example, note China's impressive achievements in R&D and scientific publications, but they caution that serious weaknesses remain in building an enterprise-centered innovation system, ensuring that R&D funds are well-spent, and protecting intellectual property. Similarly, Adam Segal distinguishes between the "hardware" and the "software" of innovation; the former refers to such key elements as money, technicians, and equipment,

while the latter includes legal protections, risk-tolerance, individual initiative, capital markets, and connections between industry and academia (Segal 2011, 22–27). Segal maintains that China and India are rapidly improving their hardware, but that strengthening their national software is just as critical and will take decades.

Culture is sometimes singled out by these writers as a key intangible element of innovation – and an area in which China and India need to improve. "While on the surface Chinese entrepreneurs and researchers are encouraged to think outside the box and not be afraid of failure," Cao, Simon, and Suttmeier write, "at least equally important is that other ingredients of a true innovation culture – autonomy, free access to and flow of information, and especially dissent, scientific as well as political – are not adequately applauded or tolerated" (Cao, Simon, and Suttmeier 2009, 258). Other scholars make a similar points with respect to China (Segal 2011, 70; Wilsdon and Keeley 2007, 34). While Indian society is comparatively free, some suggest that the extent to which such freedom works to its advantage remains to be seen. As Bound writes, "whether democracy Indian style is good for science – by providing the basis for the freedom of thought and speech critical to innovation –will be key to how India's development differs from China's" (41). Nonetheless, if there is criticism or concern about culture, these scholars also perceive potential for change. Segal, for example, refers to India's "emerging culture of entrepreneurship," while also suggesting how venture capital firms and returnees from abroad can be "carriers of the culture of innovation" (20,55, 65). James Wilsdon and James Keeley also suggest that returnees from abroad can play important roles in reshaping practices in China (Wilsdon and Keeley 2007, 30).

Other undecided scholars are primarily concerned with China and India's roles in global innovation networks (GINs) – corporate R&D activities that transcend national borders. In general, these assessments point to significant – but still limited – roles for China and India. Gert Bruche, for example, observes that China and India's roles in GINs are increasingly important but mainly confined to the information technology sector (Bruche 2009). He adds that that multinational firms' R&D in China and India is generally of lower technological value added, but notes that upgrading is in progress, and that China and India may contribute "mission critical" R&D down the road. Dieter Ernst, in turn, explores the role played by Asian countries, including China and India, within GINs in the electronics industry (Ernst 2009). He notes that these countries are doing increasingly impressive work within such networks, and that they should aspire to more important roles in the future. For time being, however, Ernst suggests that the U.S., Europe and Japan "retain their dominance in science and in high-impact intellectual property, enabling them to control the emerging new geography of knowledge" (viii). Ed Steinfeld, meanwhile, underscores how important foreign firms have become for innovation in China in particular. As he puts it, foreign-owned R&D centers "*are* the Chinese innovation system" (Steinfeld 2010, 172). But where other scholars tend to emphasize the dominance of multinationals firms in GINs, Steinfeld suggests that globalization means that commercial distinctions between "us" and "them" are increasingly blurry, and that Chinese and foreign firms often have similar interests.

Tilman Altenburg, Hubert Schmitz, and Andreas Stamm combine the two perspectives above in an assessment of China and India's progress (Altenburg, Schmitz, and Stamm 2008). That is, they suggest that scholars must consider both national

innovation systems and global networks when evaluating the progress that China and India are making. Drawing on a series of traditional indicators as well as case studies of four industries, they argue that substantial investments in each country's innovation system and extensive use of global networks have led to "partial success" (337). On the positive side of the ledger, both countries have shown growing capabilities for technology absorption, reverse engineering, and incremental innovation. Yet they conclude that both China and India lag far behind OECD countries in terms of the central focus of their study – the capacity for "new to the world" innovation. The authors conclude that China and India are likely to make inroads into the latter in the future, though they suggest that multiple scenarios are possible.

Focusing on China in particular, other scholars highlight where it excels, and suggest where it does not, by looking beyond novel product innovation. Loren Brandt and Eric Thun, for example, are not concerned with the creation of new products, but with the technological upgrading of Chinese firms (Brandt and Thun 2010). Focusing on autos, computer numerically controlled machine tools, and construction equipment, they show how some Chinese firms invest in more sophisticated technologies to upgrade their products and escape vicious price competition at the bottom of the market. Foreign firms, meanwhile, are forced to downgrade their products to compete on price. The result is a furious "fight for the middle" in which Chinese and foreign firms compete for a growing swathe of mid-range customers. Dan Breznitz and Michael Murphree also eschew a focus on novel product innovation. They emphasize instead a range of secondary innovation processes that follow the invention of new products (Breznitz and Murphree 2011). These consist of "second-generation innovation" – including the

mixing of established technologies and products to come up with new solutions – as well as organizational, incremental, and process innovation. Breznitz and Murphree contend that China excels at such secondary innovation processes and that trying to move from this specialty to novel product innovation – as the MLP and the SEI envisage – is both unnecessary and risky. Jonas Nahm and Ed Steinfeld, meanwhile, characterize China's specialty somewhat differently (Nahm and Steinfeld 2012). They argue that China excels at "innovative manufacturing," and that its particular genius lies in rapid scale-up and cost reduction. This means that Chinese firms can not only reverse-engineer existing products to make them cheaper, but also make new inventions commercially viable – whether these are invented by the Chinese manufacturer or elsewhere. It also allows creative collaborations between Chinese manufacturers and foreign companies in which knowledge can flow in both directions. In each of these studies, "innovation" in some sense is happening in China, but not necessarily the creation of new products.

Some recent scholarship on the Chinese and Indian diasporas, and the transnational flow of human capital to and from these countries in particular, also offers an ambiguous picture of their technological trajectories. The challenge that the "brain drain" – the flow of top talent to more developed countries – poses for China and India's development has long been recognized (Zweig and Chen 1995; Cao and Suttmeier 2002; Orleans 1988; Oommen 1989). More recent work indicates that this problem is still a serious challenge for both countries. Yet this work also makes clear that the flow of human talent is no longer a one-way street, and the term "brain circulation" has come into vogue (Saxenian 2002; Saxenian 2006). Denis Simon and Cong Cao note that not only have more than 300,000 Chinese students returned to China, but also that the Chinese

diaspora abroad is a considerable asset, one that facilitates knowledge flows, foreign investment, and local entrepreneurship (Simon and Cao 2009, 244). David Zweig and Wang Huiyao, in turn, have weighed China's recent efforts to lure back top talent, noting both the extent and limit of the country's success in this regard. With Lin Xiaohua, they have also described how the successes that these recent efforts have achieved have spurred China's development (Wang, Zweig, and Lin 2011). On the Indian side, recent work by Devesh Kapur has noted not only that India suffers from a serious outflow of talent, but also that this outflow creates incentives for many Indians to invest more in education in order to pursue such opportunities – a "brain gain" (Kapur 2010, 119–122). Kapur also describes how members of the Indian diaspora have contributed substantially to the development of innovation hubs like Bangalore (95). In short, the common thread here is not that the brain drain challenge has disappeared, but that both China and India are also profiting from the circulation of expertise, money, and ideas that their respective diasporas enable.

A final theme in this literature is that the future of China and India as technological powers is uncertain. Brandt and Thun are unsure who will win the "fight for the middle" between Chinese firms and MNCs that they document (Brandt and Thun 2010, 1571). They are also uncertain whether Chinese firms will successfully upgrade in other sectors, particularly if the pace of technological change is more rapid. Focusing on GINs, Ernst notes that there are both dangers and opportunities for Asian countries in such networks. GINs could be "poisoned chalices" that lock their knowledge workers into subordinate roles, or they could be opportunities to move into more challenging and rewarding innovation tasks – if Asian governments work to improve their innovation

systems (Ernst 2009, 38–42). Segal also sees the future as unclear, but he sees the United States as the key actor. The question, in Segal's view, is whether the U.S. will build on its existing strengths in the software of innovation, while also strengthening its connections to other centers of excellence around the world (Segal 2011, 237–49). For Bruche, the future depends on the interaction of conflicting forces (Bruche 2009, 280–81). China and India will benefit from growing market size, and multinational subsidiaries in these countries will presumably continue to upgrade and take on more challenging tasks. Yet he also sees risks as well. Managing global R&D networks can present a formidable challenge for Chinese and Indian companies, and there is some risk of policy change in China and India due to internal strife or geopolitical conflict.

New Directions

The preceding three sections reveal that there are widely divergent views of China and India's prospects as technological powers. There are reasons to commend, as well as criticize, each of these perspectives. The impressed scholars have marshaled an impressive array of evidence to highlight the progress that China and India have made, which in many respects is remarkable. Some of the indicators of progress, however, are of dubious value. Comparing countries in terms of invention patents recorded domestically, for example, is difficult to justify, not only because some may be recorded by foreign firms but also because there are good reasons to believe that the quality of patents granted in China are of lower quality (Liang 2012). Unimpressed scholars have done an excellent job of taking a more critical approach to the data, as well as highlighting problems in China and India's innovation systems. Yet as others have

noted, innovation has historically flourished in widely varying environments, and it remains a poorly understood phenomenon (Steinfeld 2010, 171). It is thus difficult to suggest that there is one "right way" to structure a national innovation system. The undecided scholars, in turn, have brought a welcome degree of nuance into the debate. Their reluctance to make clear-cut predictions about the future also seems wise. Yet this remains a wide-ranging literature in itself, and the scholars within it have a variety of different preoccupations. It is thus the least cohesive school of thought and the most difficult to synthesize.

In short, each school of thought has both strengths and weaknesses, and I make no pretense here of choosing one clear "winner." Instead, my purpose in this final section is to critique the literature as a whole by highlighting a few key questions that deserve more attention. First, while the growing attention to technology and innovation in China and India has been illuminating, more attention could and should be paid to variation between and within the two countries. There is a particular need for more in-depth comparisons of China and India's progress. In some ways, they may not be so different. Dieter Ernst's work on global innovation networks in the electronics industry, for example, describes both Beijing and Bangalore as third-tier "catching up" locations, lagging behind first-tier "global centers of excellence" like Silicon Valley as well as second-tier "advanced locations" in Israel, Ireland, South Korea, and Taiwan (Ernst 2009, ix). In other ways, however, they do seem to be developing at very different rates. Relying on a range of different indicators, several scholars have emphasized that China has progressed farther and faster than India, albeit to different degrees (Dahlman 2010; Chaudhuri 2012; Altenburg, Schmitz, and Stamm 2008).

To the extent that systematic differences between China and India can be identified, we should ask how they can be explained. Dahlman suggests that China's faster progress reflects a combination of greater openness and greater efforts to develop indigenous technologies. Yet it is also worth asking how much China's faster economic growth and greater market size have contributed to this tendency. Brandt and Thun, in particular, have noted the role that China's market size has played in creating opportunities for domestic firms (Brandt and Thun 2010; Brandt and Thun 2011). There are also other possible explanations that might be explored. These include differences in the national innovation systems of both countries, or possibly the extent to which governance is centralized in each country (Drezner 2001). Scholars have also argued that the key question is a political commitment to addressing market failures and creating international linkages (Breznitz 2007) or, more recently, national threat perceptions (Taylor 2012). In short, there are a range of potential explanations for differences in innovation performance between China and India that could be explored.

It would also be useful to explore in more depth the variations between particular sectors in China and India. Bruche observes that China and India loom largest in global R&D in ICT, followed by the pharmaceuticals and automotive industries. He suggests that this reflects the size of the ICT industry and its global orientation (Bruche 2009, 277). Yet there is also considerable variation within ICT. U.S. companies remain preeminent in software, both in terms of intellectual property generated and revenue, but some Chinese companies have emerged as important players in hardware. Steinfeld and Nahm, meanwhile, seem most impressed by China's role in the development of new energy technologies – notably wind, solar, and nuclear (Nahm and Steinfeld 2012).

There is thus a great degree of variation within China and India that deserves greater scrutiny as well.

Studies exploring variation between and within China and India would add insights and contribute further nuance to the debate identified in this article. Yet they could also make connections with the broader literature on technological development in developing countries. In recent years, for example, a number of scholars have suggested that attributes that promote technological catch-up – particularly the interventionist tactics of the developmental state – can become problematic when the focus becomes innovation at the technological frontier (Drezner 2001, 19–22; Breznitz 2007, 13–15; Wong 2011; Fong 1998, 341–43). As Joseph Wong writes, the point is not that no intervention is warranted, but it must be more limited, and "picking winners" is virtually impossible when the challenge is promoting innovation in science-based industries (Wong 2011, 14). While neither China nor India fits the classic developmental state model, both countries have had highly interventionist states in the past, and both governments have worked to promote domestic technology companies in recent years – with particular enthusiasm in the Chinese case. It is thus worth asking what insights this body of research can shed on China and India's development, as well as what lessons their experiences have for this growing literature. Indeed, as noted above, Naughton has already made a connection, warning that China seems to be applying catch-up tactics to innovation challenges.

If the variation between and within China and India deserves more attention, the most important gap in the literature is the lack of critical thinking about the relationship between innovation and power in the 21st century. Indeed, most of the literature in this

field devotes much more attention to the innovative capacity of China and India than to the relationship between such capacity and national power. In many ways, this is understandable. Some scholars are simply not concerned with power; it is their purpose to focus on technological innovation for its own sake, or to shed light on economic development more broadly. Scholars who do take an interest in power, in turn, may simply assume that greater capacity for innovation means greater national power and leave it at that. As suggested at the outset of this essay, international relations scholars have long seen technological creativity as an important source of national power. Must anything else be said?

The answer is yes. First, and most basically, it must be emphasized that power is not a possession of individual states, but instead arises from relationships between them. Believing otherwise, Hans Morgenthau once suggested, "is one of the most frequent and elemental errors in international politics" (Morgenthau 1961, 154). Accordingly, studies that document development in China or India, but do not compare their development with that of other countries, do not shed light on the power of these two states. The point here is not to find fault with studies that make no pretense of assessing Chinese or Indian power. Instead, it is merely to point out that these studies must be put in a larger context before they can help address this question.

Fortunately, studies interested in the "technological power" of China or India often do put them in some kind of comparative context. Typically, such studies focus on the distribution of some resource (or set of resources) that is believed to confer power when it is relatively abundant. The resource in question varies from study to study; it might be national R&D spending, the number of invention patents recorded, the quality

of the national innovation system, or the amount and quality of human capital in science and technology. Comparing such national resources undoubtedly remains important. It is insufficient, however, in a world in which innovation processes often transcend national borders. In 2010, U.S. companies invested nearly US$40 billion in R&D overseas through their foreign affiliates, with Asian countries receiving around 20 percent of the total (U.S. Bureau of Economic Analysis 2013a). Foreign firms, meanwhile, spent more than $42 billion on R&D in the U.S (U.S. Bureau of Economic Analysis 2013b). This new and growing form of interdependence means that we must consider not only what countries can accomplish on their own but also the implications of what they are doing collaboratively. To be sure, some scholars, particularly those preoccupied with GINs and human capital flows, show some appreciation of this point. We have yet to ascertain, however, how China and India's contributions to global innovation processes influences the balance of power between the countries involved.

Toward this end, scholars might usefully draw upon the literature on complex interdependence. As Robert Keohane and Joseph Nye have explained, interdependence can generate power relationships to the extent that it is asymmetric, *i.e.* one side is more vulnerable to a disruption of the relationship than the other (Keohane and Nye 1977). Nye has recently added that "perfect symmetry is quite rare, so most cases of economic interdependence also involve a potential power relationship" (Nye 2011, 55). Indeed, while China in particular has come to play an increasingly vital role in the world economy, the MLP was inspired in part by the perception that its relationship with the developed world remains decidedly unequal. In this context, it is important to ask: to what degree technological development in China and India is making their

interdependence with developed countries, and particularly with the United States, more symmetric? Some of the work reviewed above on GINs suggests that considerable asymmetry persists. On the other hand, other scholars have emphasized how China's "secondary innovation" or "innovative manufacturing" complements the work done in more developed locales – and that its contributions in this regard would be difficult to replace (Breznitz and Murphree 2011; Nahm and Steinfeld 2012). There is also much work to be done in documenting the degree of asymmetry across different industries. How do information technology, biotechnology, and new energy – to pick three prominent examples – compare in this regard? Most generally, the fact that China and India are involved in global technological innovation at all – and that MNCs are involving them in their own R&D efforts – would seem to be a step forward for these countries. Discerning just how much of a step they have taken, and where their next steps might take them, are questions that deserve greater scrutiny in the future.

A final point is that the relevance of technological capabilities to national power depends on context. That is, it is important to know not only which countries are being compared, but also what the specific issue in contention is. Nuclear weapons may be a key source of leverage in superpower crises, but worthless in counter-insurgency campaigns. To the extent that China and India are emerging as new hubs of innovation, then, we must ask in what contexts their power is enhanced – and in what contexts it is unaffected or even constrained. The answers may not be obvious. Nahm and Steinfeld point out that China has come to play an important role in new energy innovation, for example (Nahm and Steinfeld 2012). Yet this development has not apparently enhanced China's ability to deter or resist trade sanctions in this sphere: developed countries have

repeatedly pressured China over its support for new energy firms in recent years, and China has frequently backed down in response (A. B. Kennedy 2013). In the military sphere, some suggest that foreign ICT firms doing research in China are effectively training a generation of Chinese cyber-warriors. "Thousands of engineers," it is alleged, "are working to develop capabilities that could easily be drafted for cyberwarfare" (Tonelson 2013). Just how relevant such research is to cyberwarfare is debatable, however, and it is unclear that China actually needs foreign companies to develop such capabilities. Lastly, it is possible that the emergence of innovation in China and India could augment their soft power. Nye writes that "a successful economic model not only produces the latent military resources for the exercise of hard power, but it can also attract others to emulate its example" (Nye 2011, 52). Whether China or India has a distinctive model to offer the world, however, remains a hotly debated subject (S. Kennedy 2010). In short, a great deal more research is warranted before we understand how the emergence of innovation in China and India is augmenting their power – and how it is not.

* * *

While the emergence of China and India as technological powers has attracted increasing attention in recent years, we are only beginning to understand what is happening and what the consequences might be. In general, scholarship in this field has focused on the emerging capacity for innovation in these two countries. The debate that has emerged has generated a variety of useful insights, but very little in the way of

consensus. To some extent, this outcome is difficult to avoid: there is no "correct" definition of innovation and no "correct" way of measuring it, even if some approaches are more open to criticism than others. Much less attention, in turn, has been devoted to whether and how China and India's changing innovative capacities are reshaping the distribution of power in the international system. This latter question is equally important, and it deserves much greater consideration in the future.

Notes

[1] The so-called megaprojects include core electronic devices, high-end generic chips and basic software; large-scale integrated circuit manufacturing technology and associated techniques; next generation broadband mobile telecommunication; high-end numerically controlled machine tools and basic manufacturing technology; large-scale oil and gas exploration; large advanced nuclear reactors; water contamination control and treatment; new genetically modified organisms; major new pharmaceutical products; prevention and treatment of major infectious diseases such as HIV/AIDS; large aircraft; high resolution earth observation systems; manned space flights and lunar probe; and three undisclosed projects believed to serve military purposes.

[2] The seven industries include energy and environmental conservation, next generation information technology, high-end equipment manufacturing, biotechnology, new energy, new materials, and new automotive.

[3] Drawing on Herman Kahn's work on Japan, Preeg defines a "superstate" as "a nation that will almost certainly achieve great economic, technological, and financial status, that will very likely become financially and politically powerful in international affairs, and that will inevitably strive to become a military superpower as well" (2). It remains unclear what a *technology* superstate is, however, though Preeg suggests it refers to a state can rival the U.S. in this regard (111).

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