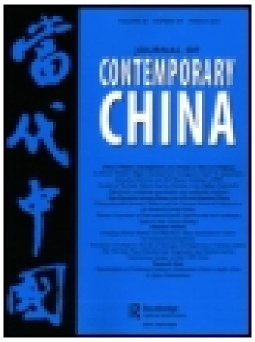

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Beyond National Innovation Systems: Incentives and China's Innovation Performance

Jon Schmid and Fei-Ling Wang

Georgia Institute of Technology, USA

ABSTRACT

This article describes the nature of innovation performance in the People's Republic of China (PRC) in the context of its changing national innovation system (NIS). More specifically, it proposes to explain China's lack of frontier innovation as reflected by the low quality of Chinese patents and scientific publications. Moving beyond the NIS—the prevailing framework for understanding national innovation rates—this article offers additional determinants to explain the unique profile of Chinese innovation. Through interviews with stakeholders from each of the three major NIS actor types and analysis of the incentive environment, two determinants of China's high rate of nominal patenting are identified. First, the incentive structure facing inventors, scientists and entrepreneurs is found to be ill-suited to promoting innovation. Second, the ubiquitous officials-rank standard (*guan benwei*) is identified as a mediating variable that amplifies the effect of suboptimal incentives in promoting nominal (as opposed to real) innovation. In essence, the authors find that ill-structured innovation incentives and the officials-rank standard work in tandem to create a high proportion of nominal innovations in the PRC.

Introduction

As part of the socio-economic reform in the People's Republic of China (PRC) since 1978, the transformation of China's national innovation system (NIS) has resulted in rapid growth of innovative outputs. Indeed, in 2012 worldwide patent applications from the PRC surpassed those from the US. However, a closer look suggests that individual units of Chinese innovative output are of lower than average quality according to various metrics. This article endeavors to explain why—given the significant improvements in China's NIS—China has failed to produce high-quality frontier innovation on a large scale.

To answer this question requires an understanding of the historical, economic and socio-political context from which the modern Chinese NIS has developed. Thus after briefly defining the NIS's conceptual environment, the authors examine China's organization of research and innovation during the command economy period (1949–1978). In the fourth section, the authors describe the manner in which economic reform has transformed China's innovation system over the past three decades. The article then considers contemporary China's record as an innovator. In particular, the authors present evidence that China is unique in that while it produces a large number of patents and scientific publications, these innovative outputs are of lower than average quality. The authors then present their answer to the question, why has China failed to produce a significant number of frontier innovations? Towards

CONTACT Jon Schmid jschmid11@gmail.com

this end, two causal mechanisms are proposed: China's ill-structured innovation incentives and the officials-rank standard (*guan benwei*). The article concludes by discussing the relevance of the findings for two prominent research veins and providing suggestions for further research and policy reform.

The NIS Defined

The theoretical foundations of the NIS—alternatively referred to as national systems of innovation—have been traced to the debate in Europe during the 1980s concerning industrial policy and the developmental state.[1] In essence, a country's NIS refers to the combination of actors, institutions and linkages that create and diffuse new scientific knowledge and technology.[2] More precisely, a country's NIS refers to the public and private actors—firms, government agencies and universities—and the relationships between them—financial, technical and social—that have as amongst their objectives the advancement or diffusion of technological progress or scientific discovery.

The NIS literature is not uniform in the components or nodes that it includes within the system under scrutiny. While additional components such as infrastructure, demand conditions, and the socio-cultural environment are occasionally included in the evaluation of a country's NIS, this article utilizes a prominent version of the theory that focuses on the primary three actor types: government agencies, firms and universities, and the relationships that connect them.[3] As will be elaborated later in the article, a country's NIS is embedded within larger socio-economic and politico-cultural contexts and the operation of each NIS actor type is dependent on the manner in which the incentives within this environment are structured and the preferences of individuals operating within the system. A broad definition of NIS 'includes all parts and aspects of the economic structure and the institutional set-up affecting learning as well as searching and exploring'.[4] In this sense, an evaluation of a country's NIS that fails to consider how the primary NIS components and their relationships are influenced by context-determined preferences and the incentive structure facing inventors may be insufficient. Thus by underscoring the importance of including the larger economic context in which a country's NIS is embedded, this article supports the inclusive definitions of innovation systems.

A country's NIS is most commonly evaluated by considering the effectiveness by which it generates, diffuses and commercializes knowledge.[5] While no perfect measures of these processes currently exist, the metrics used here—patent applications and scientific publications—approximate national performance in these areas.

A country's NIS can also be evaluated based on *how* it produces the individual 'outputs' of innovation. The NIS literature has determined that systems that are dynamic, non-linear and functionally interdependent are preferable to ones that are static, linear and functionally segregated.[6] Additionally, the NIS may be divided into two categories—myopic and dynamic—based on the manner in which the system approaches investing in technologies.[7] Myopic systems evaluate investment in the same way that a firm would: with a relatively short-term time horizon and through the utilization of straightforward evaluation measures such as return on investment. Dynamic systems, on the other hand, use longer time horizons to evaluate projects and take a more flexible approach to the investment funding decision.

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[1]Naubahar Sharif, 'Emergence and development of the national innovation systems concept', *Research Policy* 35(5), (2006), pp. 745–766.

[2]Richard R. Nelson and Nathan Rosenberg, 'Technical innovation and national systems', in Richard R. Nelson, ed., *National Innovation Systems: A Comparative Analysis* (Oxford: Oxford University Press, 1993), pp. 1–18.

[3]Ulrich Schmoch, Christian Rammer and Harald Legler, *National Systems of Innovation in Comparison: Structure and Performance Indicators for Knowledge Societies* (Dordrecht: Springer, 2006).

[4]Bengt-Åke Lundvall, 'Introduction', in Bengt-Åke Lundvall, K. J. Joseph, Cristina Chaminade and Jan Vang, eds, *Handbook of Innovation Systems and Developing Countries* (Northampton: Edward Elgar, 2009), p. 12.

[5]*Ibid*.

[6]*Ibid*.

[7]Parimal Patel and Keith Pavitt, 'National innovation systems: why they are important, and how they might be measured and compared', *Economics of Innovation and New Technology* 3(1), (1994), pp. 77–95.

Innovation in the Command Economy: 1949–1978

From 1949 to 1978 the Chinese NIS was characterized by a linear innovation model and a high degree of segregation between the actors involved in knowledge commercialization.[8] The model was distinctly hierarchical and primarily coordinated through the State Planning Commission and the institutional predecessors of the Ministry of Science and Technology. That is, the central government controlled the majority of innovation-related activity and the dominant actors engaged in R&D were national and regional government research institutes (GRI). Ties between public R&D and the private sector were weak if extant at all. This hierarchical system was situated in a policy context that explicitly sought the establishment of economic self-reliance and thus openness—foreign exchange and foreign direct investment (FDI) particularly—was low.[9]

During the Mao era, only a few elite universities such as Peking and Tsinghua were involved in basic scientific research. Similarly, firms—with the exception of large state-owned enterprises—rarely engaged in R&D, had weak ties to GRIs and produced little in terms of innovation. Weak ties between firms and the GRIs resulted in a gap between research and its commercialization. As the state gave firms a narrow mandate to manufacture—often reverse-engineered products imported from the Soviet Union and elsewhere—Chinese society lacked channels through which to update technologies, modify products or adopt novel manufacturing processes. Thus low absorptive capacity was a limiting factor in the Maoist NIS.

This period—with the exception of several prioritized projects such as atomic and hydrogen weapons, the launching of satellites and the synthesis of bovine insulin—was characterized by very low levels of innovative efficiency (innovative output as a percentage of R&D expenditure).[10] Key technologies, during this period, tended to be provided by external sources. For example, during the Mao era, the Soviet Union supplied 150 industrial projects to the PRC.[11]

During the pre-reform period, intellectual property rights (IPR) protection was low. From 1950 to 1963, only four patents were granted in China. Low IPR protection resulted in weak incentives to commercialize innovations, as the inventor had no claim to the future income associated with the innovation. Illustrative of the weak commercialization incentives is the fact that during the command period, the Chinese Academy of Sciences (CAS) produced over 40,000 inventions, but did not commercialize any of them prior to 1979.[12]

Innovation in the Reform Era: 1978–Present

Through targeted policies and government-led reform, since 1978 China's NIS has become less hierarchical and ties between the three primary actor types have strengthened. This period saw a simultaneous shift towards the market and away from the doctrine of self-reliance. Beginning with reform of the rural agricultural sector, certain manufacturing industries and the creation of special economic zones, directed economic reform has been instrumental in reshaping the Chinese NIS. Indicative of the increased priority given to innovation, during a 1978 National Science Conference, scientific and technological advancement were cited as the most important of the four modernizations.

While exposure to some market forces—such as the introduction of a competitive bidding process for government projects—began as early as 1978, the most dramatic transformation in the Chinese

[8]Xielin Liu and Nannan Lundin, 'The national innovation system of China in transition: from a plan-based towards market-driven system', in Anthony P. D'Costa and Govindan Parayil, eds, *The New Asian Innovation Dynamics: China and India in Perspective* (Hampshire: Palgrave Macmillan, 2009), pp. 27–49.

[9]Xielin Liu and Steven White, 'Comparing innovation systems: a framework and application to China's transitional context', *Research Policy* 30(7), (2001), pp. 1091–1114.

[10]Liu and Lundin, 'The national innovation system of China in transition', pp. 27–49.

[11]Philipp Boeing and Philipp Sandner, *The Innovative Performance of China's National Innovation System*, Frankfurt School—Working Paper Series, (2011), pp. 1–41, available at: http://ideas.repec.org/p/zbw/fsfmwp/158.html (accessed September 2015).

[12]Liu and White, 'Comparing innovation systems', pp. 1091–1114.

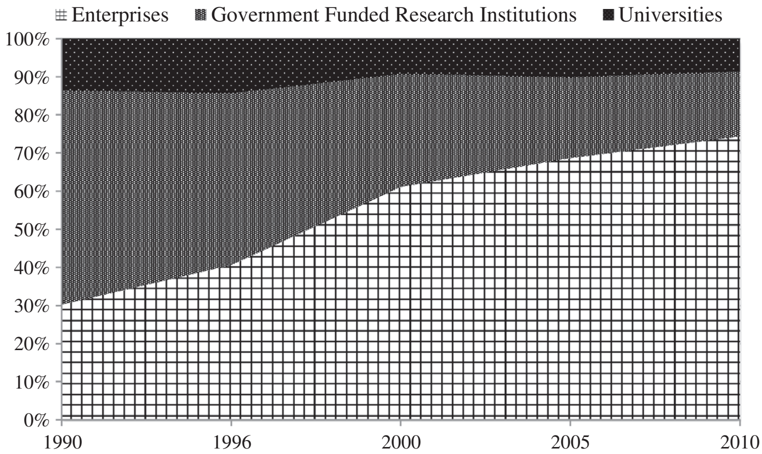

Figure 1. Allocation of R&D spending between enterprises, government funded research institutions, and universities, 1990–2010. Source: *Statistical Yearbook on Science and Technology*, 2006 and 2011.

NIS occurred during the end of the 1990s when 242 regional GRIs were decentralized and restructured. Firms also established ties to the GRIs, resulting in a sharp increase in the non-state share of total R&D spending. In 1990 firms made up only 27% of total R&D spending while by 2005 this proportion had increased to 73.4%.[13] The decreased role of the central government in Chinese R&D funding is shown in Figure 1. This shift is attributable to several factors including, the restructuring of GRIs, the liberalization of the manufacturing sector to foreign investment and the growth of post-secondary education.[14]

The 1990s also saw an increase in the strength of the linkages between the primary NIS actors. Namely, factors such as the growth of spin-offs from universities and GRIs, the increase of firm outsourcing of science and technology processes to GRIs and universities, and the increase in collaboration in scientific publications, demonstrate a strengthening of the connections between the NIS nodes.[15] The post-1978 period also saw the emergence of internal R&D departments within private firms, a positive development in the Chinese NIS as it increases competition and increases the diversity of R&D funding sources.

One of the primary changes in the modern Chinese NIS is the increased participation of foreign-based multi-national corporations (MNCs). In China, such firms tend to be technologically superior to domestic ones and have resulted in knowledge spillovers into domestic industries.[16] In essence, spillover effects are channels by which an NIS can benefit from knowledge produced abroad by forming relationships with foreign actors. However, the realization of spillover effects within the host nation requires absorptive capacity or the ability and willingness to learn from foreign companies and to adopt novel practices and technologies.[17] In China, the low absorptive capacity observed during the pre-reform period persists and has slowed the rate of technological diffusion.[18]

The overall shift in Chinese IPRs has been towards greater protection (Figure 2). Four critical laws have been enacted: the 1982 Trademark Law, the 1984 Patent Law, the 1987 Technology Contracts Law and the 1990 Copyright Law. The 1984 Patent Law has been strengthened on several occasions since it was

[13]Cha Zhimin, *China Statistical Yearbook on Science and Technology 2006* (China: China Statistics Press, 2006).
[14]See note 10.
[15]*Ibid*.
[16]Boeing and Sandner, *The Innovative Performance of China's National Innovation System*, pp. 1–41.
[17]Kui Yin Cheung, 'Spillover effects of FDI via exports on innovation performance of China's high-technology industries', *Journal of Contemporary China* 19(65), (2010), pp. 541–557.
[18]See note 16.

Year	Regulation	Effect of Regulation
1982	Trademark Law	Establishes trademark protection (administered by the China Trademark Office)
1984	Patent Law	Establishes criteria for patent protection (based on German patent law) Establishes three types of patents (invention, utility, and design)
1987	Technology Contracts Law	Increases rights to inventors to commercialize their technology through contracts
1990	Copyright Law	Establishes copyright protection
1992	First Amendment to Patent Law	Expands protection to additional industries (pharmaceuticals, food, chemical compounds) Extends duration of protection (five additional years for each patent class)
2001	Second Amendment to Patent Law	Harmonizes with international standards (TRIPS)
2009	Third Amendment to Patent Law	Increases patentability standards (absolute novelty required)

Figure 2. Creation and changes of China's intellectual property rights laws.

passed, including a 2001 amendment in accordance with WTO obligations. In 1998 individual inventors became eligible to receive a 35% royalty on inventions generated while working for a government agency. According to Walter Park's index of patent protection, China has increased its IPR protection significantly during each of the last three periods of measurement (1995, 2000 and 2005).[19] The 2005 score, the most recent available, places China 34th amongst the 122 indexed countries.

China's IPR protection, however, remains weak in certain areas. The Global Intellectual Property Centre recently ranked 25 countries in terms of the strength of IPR protection. Of these countries, China ranked 17th. In this report, China ranked high in terms of patent protection, but low in trademark protection and trade secret protection.

In February 2006, the PRC State Council presented its 15-year National Outline for Medium and Long Term Science and Technology Development Planning. The Plan is a continuation of the policies initiated towards the end of the 1990s to expand R&D, increase the role of the market and build a top quality research system.[20] The 2006 plan set ambitious targets for China to become a world leader in both innovation and the production of knowledge as measured through the publication of scientific journal articles. One of the plan's most ambitious targets is to increase R&D intensity (R&D expenditure as a percentage of GDP) from 1.3% to 2.5%. The plan also emphasized the desire to develop 'indigenous innovation', aiming to decrease reliance on imported technology to 30% by 2020.

China has also established ambitious goals in terms of patenting. In its 12th five-year plan (2011–2015) an overt Patent Development Strategy was created. The Strategy set the goal of producing two million patents per year (invention, utility and design patents combined) by 2015.[21]

In summary, compared to the pre-1978 NIS, the post-reform Chinese NIS has made significant improvements by means of increasing private sector involvement, decreasing system hierarchy, increasing system openness and strengthening IPR protection. However, the Chinese NIS still lacks strong protection for trademarks and trade secrets and has relatively low absorptive capacity. Moreover, as is argued later, the current Chinese NIS needs to be understood in the larger socio-economic and cultural contexts in which it operates.

[19]Walter G. Park, 'International patent protection: 1960–2005', *Research Policy* 37(4), (2008), pp. 761–766.
[20]Sylvia Schwaag Serger and Magnus Breidne, 'China's fifteen-year plan for science and technology: an assessment', *Asia Policy* 4(1), (2007), pp. 135–164.
[21]'China's IQ (innovation quotient): patenting, in depth', *Thomson Reuters*, available at: http://ip.thomsonreuters.com/sites/default/files/chinas-innovation-quotient.pdf (accessed July 2015).

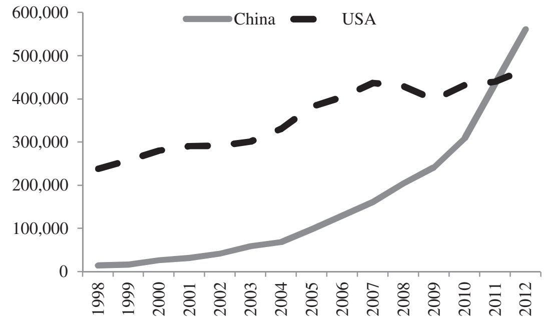

Figure 3. China vs. US annual patent applications, 1998–2012. Source: WIPO, 2013.

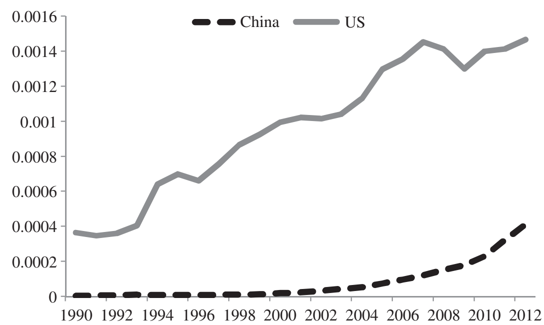

Figure 4. China vs. USA annual per capita patent applications, 1990–2012. Source: Population Data (World Bank), Patent Data (WIPO, 2013).

China's Record of Innovation

There are two primary features of the innovation produced by China's new NIS: rapid nominal output growth and lower than average quality of these outputs. Using two of the primary measures by which innovation is approximated—patent applications and scientific publications—the authors explore these two features.

Figure 3 demonstrates the explosive growth in Chinese patent applications from 1998 to 2012. In fact, patent applications in China exceeded those of the US in 2012 and the Chinese patent office in 2013 surpassed the United States Patent and Trademark Office (USPTO) as the world's largest patent office in terms of application volume.[22]

From 1990 to 2012, annual per capita patent applications in China grew 23.1% vs. 7.2% in the US. While sustaining such a growth trajectory is unlikely, at China's current growth rate it will double its patent application output every 3.34 years as opposed to every 10 years for the US. Per capita output comparisons, however, show that China still trails the US by a significant margin. In 2012, China filed 4.15 patents per 10,000 citizens while the US filed 14.66 applications per 10,000 citizens (Figure 4).[23]

Scientific publications are another common proxy for a country's innovation capacity. China's growth in this area has also been substantial. In 2012, according to the SCImago Journal & Country Rank, the United States was the world's top producer of scientific publications contributing 537,308 articles (17.1 per 10,000 persons), while China was the second highest publisher generating 392,164 articles (2.9 per

[22] Jeffrey Shieh, 'Will China pass the US as the world's top IP market?', *Forbes*, (11 March 2013), available at: http://www.forbes.com/sites/ciocentral/2013/03/11/will-china-pass-the-u-s-as-the-worlds-top-ip-market/#35f96bb2617a (accessed July 2015).
[23] Authors' calculations. Population data are from the World Bank; patent data are from WIPO.

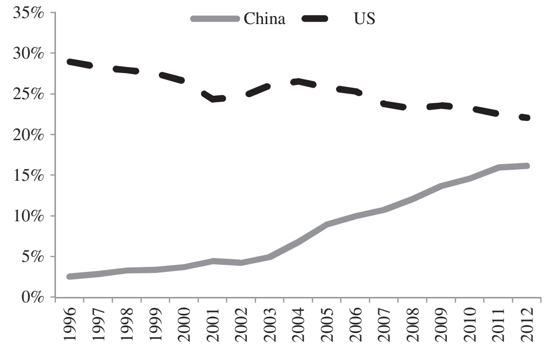

Figure 5. Percentage of world scholarly output, China and US, 1996–2012. Source: SCImago.

10,000 persons). However, China's recent publication growth rate has exceeded that of the US. From 1996 to 2012, Chinese output of scientific publications grew by 18.6% per year while that of the US grew by 3.2%. China is rapidly catching up with the US as the world's leading producer of scientific publications in quantity (Figure 5).

While the result of the more open, less hierarchical and more integrated Chinese NIS on innovation output has been substantial, a closer look at the patent and scientific publication data raises questions regarding the importance or quality of Chinese innovation. Citations are a common proxy for the quality of a unit of innovation. Important contributions will tend to be heavily cited as subsequent works rely on them to advance knowledge.[24] For the nearly four million patent applications filed with the USPTO from 1975 to 2010, the average number of forward citations is 9.30 and the mean for Japanese and American patents is 7.45 and 11.33, respectively.[25] However, the average number of forward citations for patents filed by Chinese assignees was only 2.12.

The argument could be made that part of the reason for the failure of Chinese patents to accumulate citations is due to a time truncation effect. That is, because Chinese patent growth has increased faster than the world average in recent years, the average Chinese patent had less time to receive citations from other patents. However, after correcting for truncation due to time—using the weights devised by Hall, Jaffe and Trajtenberg—the pattern described above persists.[26] The mean number of weighted citations for the over three million patent applications filed with the USPTO from 1976 to 2006 is 11.76 and this figure for Japanese and American patents is 10.7 and 14.44, respectively.[27] However, the mean number of weighted citations for Chinese patents is 5.22.

Third-party research supports the contention that Chinese patent quality is lower than average. A report by Thomson Reuters looks beyond mere patent application counts and assigns weights based on indicators of quality.[28] The report weighs firms' patent applications based on success in being approved, having sought patent protection from the four major patent authorities, forward citations received and the volume of applications.[29] Using this revised measure of patent output, firms were ranked according to innovativeness. There were no Chinese firms on the list of the top 100 innovators. A 2014 report reached a similar conclusion.[30] Namely, researchers noted that of 2,008 data processing patents,

[24]M. B. Albert and D. Avery, 'Direct validation of citation counts as indicators of industrially important patents', *Research Policy* 20(3), (1991), pp. 251–259.

[25]Bhaven N. Sampat, 'USPTO patent and citation data', *Harvard Dataverse*, available at: http://hdl.handle.net/1902.1/16412 (accessed June 2015).

[26]Bronwyn H. Hall, Adam B. Jaffe and Manuel Trajtenberg, *The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools* (National Bureau of Economic Research, 2001), available at: http://www.nber.org/papers/w8498 (accessed June 2015).

[27]The Hall, Jaffe and Trajtenberg weights are only available for the 1976–2006 dataset.

[28]'Top 100 global innovators', *Thomson Reuters*, available at: http://top100.ctpboston.com/top100 (accessed July 2015).

[29]The four patent authorities in question are the Chinese Patent Office, the European Patent Office, the Japanese Patent Office and the USPTO.

[30]'China's IQ (innovation quotient)', *Thomson Reuters*.

Chinese patents received an average of 1.17 forward citations compared to 6.72 for the US. Similarly, a report from *The Economist* supports the contention that a portion of the increase in patent output in China may be illusory, noting that Chinese patent holders were less likely to file for protection outside of China.[31] Specifically, while 27% of American and 40% of European patent holders sought patent protection outside of their home country from 2005 to 2009, only 5% of Chinese patent holders did.

One measure of patent output that incorporates patent quality is the h-index. The measure—borrowed from bibliometrics—combines the number of patents produced by an individual or organization and the number of forward citations these patents receive into a single metric. An entity can be said to have an h-index of *h* when it produces *h* patents each of which receives at least *h* forward citations. For example, the University of California system during the period of 1990–2008 had a patent h-index of 86, the highest of any academic institution.[32] This means that the University of California system produced 86 patents that each received at least 86 citations.[33] Comparing the h-index of Chinese academic institutions to their raw patent application counts underscores the distinction between quantity and quality in Chinese patents. While ranking academic institutions based on patent application counts reveals that the top five academic institutions are all Chinese, only one Chinese university (Tsinghua University) ranks in the top five institutions ranked by h-index.[34]

Citation-based measures can also be used to provide an indication of the quality of a scientific publication. Over the period of 1996–2012, Chinese publications received an average of 4.21 citations while those of the US received 18.34 citations.[35] As in the case of patents, the h-index can be used to illustrate the paradox of Chinese innovative quality as related to scientific publications. While in 2012 China ranked second in the world in terms of raw publication output, it ranked 16th in h-index and 174th in terms of citations per document. These findings are consistent with the patent application data and the authors' contention that innovation in China tends to be of the incremental rather than the new-to-the-world variety. It should be noted, however, that publication databases contain a known coverage bias in favor of American publications and a strong bias against publications in languages other than English.[36]

A portion of the low rate of citation amongst Chinese publications is attributable to the proliferation of low quality journals that has characterized the Chinese academic system. Such journals often charge authors for publishing their works. There are over 5,000 local academic journals in China, many of which are best characterized as commercial ventures rather than means for vetting and distributing novel knowledge.[37]

Finally, Chinese scientific publications have been tainted by plagiarism, falsification and fraud. Academic corruption seems to have contributed to the overall low quality of Chinese scientific publications.[38] The authors' interviews with professors and administrators within elite Chinese universities (the so-called 211 and 985 schools) reveal that academic corruption is endemic.[39] In fact, the purchase of plagiarized research articles and books has become so widespread in the PRC that an industry complete with 'full customer service' has developed.[40] While a fraudulent scientific paper may cost only US$250,

[31]'How innovative is China? Valuing patents', *The Economist*, (5 January 2013), available at: http://www.economist.com/news/business/21569062-valuing-patents (accessed June 2015).

[32]Chunjuan Luan, Chunyan Zhou and Aiyun Liu, 'Patent strategy in Chinese universities: a comparative perspective', *Scientometrics* 84(1), (2010), pp. 53–63.

[33]In this analysis the ten campuses of the University of California system were not disaggregated.

[34]Luan *et al.*, 'Patent strategy in Chinese universities', pp. 53–63.

[35]'SCImago journal & country rank', *SCImago*, available at: http://www.scimagojr.com (accessed June 2015).

[36]Li Tang and Guangyuan Hu, 'Tracing the footprint of knowledge spillover: evidence from US–China collaboration in nanotechnology', *Journal of the American Society for Information Science and Technology* 64(9), (2013), pp. 1791–1801.

[37]David Cyranoski, 'Strong medicine for China's journals', *Nature News*, (15 September 2010), pp. 261–261, available at: http://www.nature.com/news/2010/100915/full/467261a.html (accessed June 2015).

[38]Jane Qie, 'Publish or perish in China', *Nature News*, (12 January 2010), pp. 142–143, available at: http://www.nature.com/news/2010/100112/full/463142a.html (accessed June 2015).

[39]Fei-Ling Wang, personal communication, various dates.

[40]Zhouzi Fang, 'Shijie yiliu daxue jianshi yu xueshu guifan' ['Building World Class University and Academic Standard'], Speech at Zhejinag University, 27 November 2005.

reaching the position of Academician within the CAS would reportedly require illicit spending of US$3.8 million.[41] In 2009, 70 crystallography structures submitted by PRC researchers were retracted by a single British journal.[42] In a 2010 Chinese government survey, over a third of 6,000 PRC scientific researchers at six leading institutions admitted to plagiarism, falsification or fabrication, compared to about 2% in the West.[43] In 2010, the *Journal of Zhejiang University—Science* found that 31% of the submissions they received over a two-year period contained plagiarism.[44]

Explaining the Low Quality of Chinese Patents and Publications: Innovation Incentives and the Officials-rank Standard

This section aims to identify the mechanisms responsible for the low quality of Chinese patents and publications. The section begins by describing the data and methods utilized. The authors then compare research on incentivizing innovation with the observed innovation incentive structure of China. The section concludes by describing the officials-rank standard as a mediating factor in nominal patenting and publishing in the PRC.

Data and Methods

This article utilizes three sources of data: secondary source research; primary source policy documents; and in-person interviews. The secondary sources are used to describe the current state-of-the-art on incentivizing innovation at the level of the individual. This research is used to construct a sort of ideal type with which the empirical case can be compared. It is the significant divergence between this ideal type and the observed incentive environment in China that constitutes this article's primary explanation for China's low quality of innovation.

The second source of data is primary source policy documents. These documents are used to construct what may be considered China's official innovation policy. The documents used include the 2006 Medium and Long Term Plan for Science and Technology Development (MPL), the 2008 National Intellectual Property Strategy (NIPS), the 2010 National Patent Development Strategy (NPDS), the 2010 Twelfth Five-Year Guideline, various five-year sub-plans for specific scientific and technological fields, and the annual National Reports on Science and Technology Development produced by the PRC Ministry of Science and Technology.

Whereas these official policy documents shed light on the PRC's ambitions and official high-level strategies for promoting innovation, to capture the effect of innovation policy at the level of individual researchers it is necessary to consult these researchers directly. Towards this end, this article conducted 40 semi-structured interviews with researchers, government officials and business managers over a three-year period (2010–2013). In-person interviews were conducted in China, Hong Kong, Macao and the United States. Of the 40 interviews, 23 were conducted in-person, and the remainder were conducted by phone. In some cases, follow up questions were sent via e-mail.

Interviewee selection was informed by the NIS framework, which suggests that innovation is largely dependent on the behavior and interaction between three actor types: universities, governments and firms. Thus care was taken to select subjects from each of these categories. While the interviewee selection process was informed by NIS theory, interview protocols were constructed so as to elucidate the two determinants—the incentive structure and the officials-rank standard—identified here as contributing to the PRC's high rate of nominal patenting and publishing. The authors interviewed 20 individuals from 11 Chinese universities: Tsinghua University, Peking University, Fudan University, Zhongshan University,

[41]Jing Fang, 'Hulianwang shang de lunwen heishi' ['Online black market for papers'], *CCTV Jiaodian fangtan* [*Focus Interviews*], (14 January 2006).
[42]Qie, 'Publish or perish in China', pp. 142–143.
[43]'How innovative is China?', *The Economist*.
[44]Yuehong Zhang, 'Chinese journal finds 31% of submissions plagiarized', *Nature* 467, (2010), pp. 153–153.

Chinese University of Science & Technology, Shanghai Jiaotong, Tongji University, Wuhan University, Huazhong University of Science & Technology, Xiamen University and Zhejiang University. Eight of them are listed in US News' China's Top Ten universities. The majority of on-site university interviews were conducted with university professors actively engaged in scientific research. However, in six cases, university administrators and non-faculty researchers were interviewed. From the private sector, the interviewee selection criterion was that subjects must hold management level positions within firms that engage in R&D spending. For public sector employees, the selection criterion was that the officials must be involved with the administration, production or commercialization of scientific knowledge or technology. Business managers and government officials were interviewed in five Chinese cities: Beijing, Shanghai, Wuhan, Guangzhou and Shenzhen. Finally, the authors were able to interview several researchers from the CAS.

Incentivizing Innovation

The optimal incentive environment for innovation is distinct from that associated with processes that are further downstream. Specifically, incentivizing innovation is characterized by the relative ineffectiveness of external rewards in stimulating creative thinking, the importance of *intrinsic* rewards to creative labor, the degree of autonomy given to scientists and researchers, and the uncertain nature of research. This section briefly explores the literature on incentivizing innovation on the individual level in order to identify the areas in which the incentive structure in the PRC may shape the distinctive character of Chinese innovative output.

One of the primary justifications for the provision of financial incentives to increase worker productivity relates to the principal–agent problem that arises when information between parties is asymmetrical. That is, when an input to production—such as an agent's effort—is not fully observable, an incentive that is tied to that agent's productivity may align parties' interests and reduce the effort shortfall associated with imperfect monitoring. Such productivity incentives have proved useful in increasing output in tasks that are primarily a function of effort.[45] However, incentives that are directly tied to short-term output may fail to enhance—and indeed may diminish—productivity for processes that require workers to reach creative solutions or that require experimentation, exploration and frequent failure.

Using a modified version of the traditional principal–agent model, it has been shown that the optimal incentive conditions for innovation requires patience for early failures and an expanded time horizon for evaluating success.[46] In this context, the utilization of traditional performance-based incentives will discourage the experimentation critical for successful innovation. Similarly, a computational agent-based model has demonstrated that performance incentives often produce a glut of good ideas, but do little to stimulate the generation of extraordinary ones.[47]

As opposed to downstream manufacturing processes where labor monitoring can be achieved through standard metrics, monitoring labor that involves creative processes is complicated by the high degree of uncertainty in outcomes. That is, there is a higher degree of failure risk associated with such processes and thus monitoring that is based on output may fail to appropriately reward creative effort. A comparison of researchers funded by two distinct grant-funding schemes—that of the Howard Hughes Medical Institute (HHMI grants) and the National Institute of Health (NIH)—illustrates the importance of tolerance for early failure in innovation.[48] The study finds that researchers operating under funding conditions that tolerate early failure and have longer time horizons (i.e. those under the HHMI funding schemes) are significantly more successful in producing innovative research than those working under

[45] Edward P. Lazear, 'Performance pay and productivity', *The American Economic Review* 90(5), (2000), pp. 1346–1361.

[46] Gustavo Manso, 'Motivating innovation', *The Journal of Finance* 66(5), (2011), pp. 1823–1860.

[47] Oliver Baumann and Nils Stieglitz, 'Rewarding value-creating ideas in organizations: the power of low-powered incentives', *Strategic Management Journal* 35(3), (2014), pp. 358–375.

[48] Pierre Azoulay, Joshua S. Graff-Zivin and Gustavo Manso, 'Incentives and creativity: evidence from the academic life sciences', *RAND Journal of Economics* 42(3), (2011), pp. 527–554.

grants that require successful completion of predefined deliverables as a condition of continued funding and that are of shorter duration (i.e. NIH grants).

Experimental psychology offers insight into the complex relationship between external rewards and innovative thinking. A seminal study finds that providing high school students with a reward for participating in an activity decreases their performance in a verbal task relative to a control group that does not receive a reward.[49] Since demonstrating that rewards might have negative effects on performance, more recent research has suggested that intrinsic motivation may be more important in driving creative work than extrinsic incentives such as financial rewards.[50]

Scholars of the determinants of individual innovative productivity often make a distinction between motives and incentives. While incentives refer to monetary rewards contingent upon completing a task, an individual's motives refer to a set of preferences amongst a broader range of factors that determine level of work. Such factors may include intellectual challenge; peer recognition; improving society; and the desire for power, increased responsibility or job security. Incentives can thus be thought of as the increased income associated with completing a particular objective, while motives refer to the extent to which an individual values that income relative to the non-pecuniary benefits of work. Motives thus mediate incentives, determining their effectiveness in producing the desired result. If the motives of a given individual are such that traditional pay-for-production incentives are subordinate to other factors, such incentives may fail to produce their intended results.

Empirical evidence on the motives of scientists supports the contention that non-pecuniary factors are important in determining an individual's motives to innovate.[51] Using survey data of over 1,700 Ph.D.-holding scientists and engineers, it was found that an individual's desire for intellectual challenge, increased income and independence are associated with a greater propensity to patent.[52] However, a high predilection for job security and increased responsibility were negatively associated with an individual's propensity to patent. In another survey of over 30,000 science and engineering Ph.D.s, 79% of respondents indicated 'intellectual challenge' to be a very important aspect of their job while only 43% gave salary similar standing.[53] When compared to production workers, scientists and engineers assign greater weight to non-pecuniary incentives.[54]

While motives such as intellectual challenge and enjoying one's work appear to play a particularly significant role in determining creative productivity, the role of intrinsic motives may be augmented by the high degree of autonomy associated with research professions.[55] It has been documented that both academic and private sector research workers enjoy considerable autonomy in determining the tasks on which they work.[56] In such a setting, an individual's motives will influence behavior to a greater degree than in environments where discretion is low. Thus, the combination of worker autonomy and a preference for satisfying and challenging work may crowd out the influence of traditional extrinsic incentives.

While individuals involved in innovation appear to be significantly motivated by non-pecuniary factors, it is important to note that differences in individuals' motivations may not necessarily translate into differences in firm-level inventiveness. However, there is circumstantial evidence to support

[49]Arie W. Kruglanski, Irith Friedman and Gabriella Zeevi, 'The effects of extrinsic incentive on some qualitative aspects of task performance', *Journal of Personality* 39(4), (1971), pp. 606–617.
[50]Beth Hennessey and Teresa M. Amabile, 'Reality, intrinsic motivation, and creativity', *American Psychologist* 53(6), (1998), pp. 674–675.
[51]Henry Sauermann, *Individual Incentives as Drivers of Innovative Processes and Performance—Executive Summary*, SSRN Scholarly Paper, (2008), available at: http://papers.ssrn.com/abstract=1371668 (accessed July 2015).
[52]Henry Sauermann and Wesley M. Cohen, 'What makes them tick? Employee motives and firm innovation', *Management Science* 56(12), (2010), pp. 2134–2153.
[53]Wesley M. Cohen and Henry Sauermann, *Schumpeter's Prophecy and Individual Incentives as a Driver of Innovation*, SSRN Scholarly Paper, (2007), available at: http://papers.ssrn.com/abstract=2254959 (accessed July 2015).
[54]*Ibid*.
[55]*Ibid*.
[56]Henry Sauermann and Paula E. Stephan, *Twins or Strangers? Differences and Similarities between Industrial and Academic Science*, SSRN Scholarly Paper, (2010), available at: http://papers.ssrn.com/abstract=1626602 (accessed July 2015).

this link. In a study of drug manufacturers, firms in which researchers were widely connected to the external scientific community performed better than their unconnected peers in terms of drug development.[57] This relationship might be explained by a sort of attraction effect whereby firms that allow their scientists to engage with the scientific community attract employees that are inclined to produce innovative research.[58]

China's Incentives to Patent and Publish

While innovation might not be responsive to traditional pay-for-performance incentives, in the PRC patenting and publishing appear to be. Through the 2006 Medium and Long Term Plan for Science and Technology Development (MPL), the 2008 National Intellectual Property Strategy (NIPS) and 2010 National Patent Development Strategy (NPDS), the Chinese government established patent targets and provided direct incentives to researchers and institutions to patent and publish.[59] This planning-style of funding and assessment has led to a strong preference amongst researchers and institutions for reaching stated objectives, which are often based on countable units of innovation such as patents and publications. The short time horizon of these targets discourages early failure. Rather than spurring genuine innovation, these incentives appear merely to have changed how patenting and publishing occurs in the PRC. That is, by setting targets and offering direct incentives to patent and publish rather than incentivizing creativity itself, these reforms appear to have stimulated nominal rather than real invention.

China has established an innovation incentive mix that includes tax breaks for innovative firms, allowing universities to commercialize intellectual property developed during government-funded research projects, subsidization of the patent application process, financial incentives to Chinese nationals that file patents abroad, and direct rewards to researchers. Direct rewards, given to researchers for publishing, include promotions, cash prizes, housing allocations and overseas travel.[60] In short, the direct incentives appear to have produced the incentivized outcome—namely, a publication or patent—but not the underlying objective—a contribution to science or technological change.

In 2002, the Ministry of Finance and the Ministry of Science and Technology jointly passed a regulation that allowed organizations such as universities the right to commercialize intellectual property developed under government-sponsored research projects. Occasionally referred to as the 'Chinese Bayh–Dole Act', the law meant to emulate the 1980 American law and stimulate innovation. The response to the 2002 regulations has been significant. While universities were responsible for only 6% of all patents submitted to the SIPO (State Intellectual Property Office) in 2000, Chinese universities filed 16% of all patents in 2010. However, the 2002 regulations may have merely increased Chinese universities' propensity to file patents rather than the extent to which they innovate. A study of university patents in the PRC indicates that the growth in quality—measured by forward citations—was less than the growth in quantity following the 2002 reform.[61]

Another means by which patenting has been incentivized by the PRC is through the subsidization of patent filing costs. In 1999 Shanghai enacted China's first patent application subsidy program and by 2003 the majority of other provinces had followed suit.[62] While the various patent application subsides differ in detail, they all aim to reduce the cost of filing patent applications by financing all or a portion of the investor's cost of filing the claim. Some even offer financial rewards to successful patent

[57]Iain M. Cockburn and Rebecca M. Henderson, 'Absorptive capacity, coauthoring behavior, and the organization of research in drug discovery', *The Journal of Industrial Economics* 46(2), (1998), pp. 157–182.
[58]Cohen and Sauermann, *Schumpeter's Prophecy and Individual Incentives as a Driver of Innovation*.
[59]For a discussion of local innovation-promotion initiatives see, Tse-Kang Leng and Jenn-Hwan Wang, 'Local states, institutional changes and innovation systems: Beijing and Shanghai compared', *Journal of Contemporary China* 22(80), (2013), pp. 219–236.
[60]See note 42.
[61]Christian Fisch, Jorn H. Block and Philipp G. Sandner, *Chinese University Patents: Quantity, Quality, and the Role of Subsidy Programs*, SSRN Scholarly Paper, (2013), available at: http://papers.ssrn.com/abstract=2304224 (accessed July 2015).
[62]Xibao Li, 'Behind the recent surge of Chinese patenting: an institutional view', *Research Policy* 41(1), (2012), pp. 236–249.

applicants. However, a comparative study of five Chinese cities suggests that such incentives may have produced a dilution effect. In June 2006, the city of Zhangjiagang enhanced their patent incentive structure in two ways. First, the city increased the subsidy given to patent applicants from 1,500 to 3,000 *Renminbi*. Second, the city established a system whereby accepted patent applicants would be given a direct financial reward of 10,000 *Renminbi*. The patent incentive schemes in the four neighboring cities remained unchanged over the period examined. This natural experiment allowed researchers to determine the effect of the novel incentive structure on patent applicant behavior. In particular, while the total number of claims per patent applicant remained unchanged, these claims were broken into a greater number of patent applications. Thus while inventiveness was not enhanced by the subsidies and rewards, the number of applications was responsive to the new incentive structure.

It should be noted that this dilution effect is not universally observed. While patent application subsidies appear to increase the rate at which firms, universities and individuals patent, there is no observed fall in the patent grant ratio (patents granted as a ratio of patent applications). This result suggests that—assuming the evaluation criteria has not changed—the quality of patents has not fallen due to the subsidies. However, it is possible that local patent offices are motivated by factors other than the merit of the claims they process. It has been reported that patent officers are paid based on the number of the patents they approve.[63] It has also been found that there is a surge of patent applications in December in the PRC, which suggests that a portion of the applications filed at the end of the year are politically motivated.[64]

The PRC also employs fiscal incentives to innovation in the form of tax breaks. Such fiscal incentives may be preferable to direct funding, as they do not distort the innovation funding process by selecting the technologies that receive subsidies.[65] The 2006 MPL provides for an increase in the tax deductibility of R&D expenditure—to 150%—and to increase the rate at which R&D equipment can be depreciated on balance sheets. Studies of such tax credits in other countries have suggested they are efficient means by which corporate R&D is stimulated.[66]

The field interviews and email exchanges support the notion that direct inducements result in a dilution in quality in both patents and scientific publications. During an interview with a university administrator, the interviewee indicated that the institution was assigned a patent registration quota that the university was required to meet.[67] A senior scientist at a government research lab also mentioned the existence of patent quotas. When this scientist was asked what would happen should the agency fail to meet their patent quota, the scientist responded, 'you'll lose funding or else you have to work much harder the next year'.[68]

During another interview, a young researcher based in a major university elaborated on the relationship between the university and government sector, stating, 'We often compete to produce numbers, not always useful stuff, even fake results, because the [university] cadres need [the numbers] to show their bosses'.[69] A different interviewee (a researcher at a government research agency) described the relationship between job promotion and patenting. Specifically, in describing the actions of a non-research official, the interviewee explained that as many as 200 patents were filed in one particular year, 'to beat the deadline' for promotions.[70]

[63]'Patents, yes; ideas, maybe', *The Economist*, (14 October 2010), available at: http://www.economist.com/node/17257940 (accessed June 2015).

[64]Zhen Lei, Sun Zhen and Brian Wright, 'Are Chinese patent applications politically driven?', presented at the *2012 Patent Statistics for Decision Makers Conference*, (2012), available at: https://www.oecd.org/site/stipatents/4-3-Lei-Sun-Wright.pdf (accessed July 2015).

[65]Robert D. Atkinson, 'Expanding the R&E tax credit to drive innovation, competitiveness and prosperity', *The Journal of Technology Transfer* 32(6), (2007), pp. 617–628.

[66]Dominique Guellec and Bruno van Pottelsberghe de la Potterie, 'The internationalisation of technology analysed with patent data', *Research Policy* 30(8), (2001), pp. 1253–1266.

[67]Fei-Ling Wang, personal communication, 2010.

[68]Fei-Ling Wang, personal communication, 2013.

[69]*Ibid*.

[70]*Ibid*.

The dilution effect of direct incentives was also observed in the production of scientific publications. During one conversation, a university researcher indicated that he was 'faking it' in terms of generating publications.[71] Numerous scholars at top universities indicated that the criterion for hiring and promotion was number of publications and that little attention was paid to the quality of scholarly output. Some claimed that raises were routinely dependent on article counts rather than article quality or article impact.[72]

The Officials-rank Standard

The officials-rank standard (*guan benwei*)—alternatively 'government official-oriented'—refers to a ubiquitous socio-political hierarchy that affords deference and prestige to government officials and other forms of official ranking. This rigid and pervasive socio-political system determines one's professional rank, pay, perks, status and power. The officials-rank standard acts as a mediating variable in that it shapes the way in which the incentive environment affects patenting and publishing.

Comparing the non-pecuniary benefits and embedded values associated with the officials-rank standard to those found to be conducive to creative work reveals an environment ill-suited to producing innovation. In China, prestige and other non-pecuniary benefits of official employment are often sufficient to dominate more traditional determinants of job selection such as salary.[73] Because occupancy of an official government position is considered the pinnacle of professional accomplishment, scientific and entrepreneurial talent is funneled to the official sector.[74] Experimental research on Chinese students supports the contention that the officials-rank standard affects behavior on the individual level.[75] The interviews suggest that even foreign-educated scientists measure professional success by official rank, titles and the associated perks. Indeed the majority of interview subjects had been appointed to various positions with 'office-equivalent' ranks and titles. Because non-pecuniary benefits have been documented to be critical motivating factors for scientists and researchers, motives such as intellectual challenge that are suited to innovation appear to be crowded out by a preference for official ranking. Similarly, *guan benwei* emphasizes the importance of non-pecuniary factors such as increasing one's professional responsibilities and job security, motives that relate negatively to innovation.[76]

Besides shaping preferences towards job-security, rank and responsibility, the officials-rank standard encourages conservatism and conformity and discourages individualism and creativity. To be liked and trusted by the CCP official in charge of personnel is critical for scientists seeking an official rank or a promotion in rank.[77] Such conditions stifle the dissent and originality necessary for pursuing the unconventional lines of inquiry that often lead to genuine innovations. Research suggests that national cultures that are characterized by individualism rather than collectivism provide greater social rewards to individual innovators.[78] As the officials-rank standard discourages individualism and allocates scarce social rewards based on official standing, this mechanism for promoting innovation is crowded out.

Besides shaping preferences and discouraging creativity, the officials-rank standard influences the allocation of research funding, faculty retention and promotion decisions. CCP committees monitor all state-owned or state-funded research and educational institutions and the majority of R&D institutions. Such committees are led and largely staffed by professional full-time party cadres who are

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[71] Fei-Ling Wang, personal communication, 2011.

[72] See note 39.

[73] Yingjing Wang and Hanhui Hu, 'The cultural path-dependence in the process of Chinese entrepreneurs', *4th IEEE International Conference on Management of Innovation and Technology*, (2008), pp. 815–820.

[74] *Ibid*.

[75] Lei Zhen, *Can Official Rank Standard Affect Individuals' Behavior in China?—A Framing Effect Investigation*, Very Preliminary Working Paper, (2011), available at: http://excen.gsu.edu/docs/Zhen%20Lei_11.15.2011.pdf (accessed June 2015).

[76] Sauermann and Cohen, 'What makes them tick?', pp. 2134–2153.

[77] See note 39.

[78] Yuriy Gorodnichenko and Gerard Roland, *Culture, Institutions and the Wealth of Nations* (National Bureau of Economic Research, 2010), available at: http://www.nber.org/papers/w16368 (accessed July 2015).

tasked with ensuring the obedience of researchers.[79] Researchers typically aim to secure official cadre or cadre-equivalent positions, which increases the deference afforded to behavior in line with the officials-rank standard.[80] CCP cadres make final decisions regarding the allocation of funds, employment and promotion. The influence of these officials (or researchers holding official positions) can shape the direction in which research proceeds and their presence ensures a prominent place for the officials-rank standard within research institutions.

While researcher autonomy can be considered a sort of enabling condition for innovation, it is largely absent from the Chinese NIS, which is characterized instead by a high degree of worker oversight and hierarchy.[81] Such supervision and bureaucracy are stifling to the scientist. During the interviews multiple scientists expressed a desire for research autonomy and characterized the CCP as meddlesome. One scientist expressed this sentiment succinctly, stating that he preferred to be 'left alone to do research'.[82] The stifling effect of constant supervision is exacerbated by the fact that non-experts often undertake supervision of research in China, a fact that complicates the task of supervision while facilitating the act of passing nominal research as a true scientific contribution. State officials monitor the short-term patent and publication targets and other state-mandates described above. As these bureaucrats are typically inexpert in the fields in question, when comparing researchers they often merely count publications rather than evaluating the quality of the work in question.[83]

The enduring socio-political and cultural norms of the officials-rank standard superimposed on an otherwise vibrant capitalistic economy creates a sort of path dependence whereby real innovation is underprovided due to its relatively low social standing. The officials-rank standard and the suboptimal incentives can be understood as working in tandem to create an overall incentive environment that provides little recompense to genuine innovation and rewards output rather than the creative process.

Conclusion

This article has attempted to first identify the existence of a paradox: the continued low quality of Chinese innovation despite significant improvements in that country's system of innovation and high levels of R&D spending. Second, this article provides a plausible explanation for this paradox based on the suboptimal nature of the innovation incentive structure in the PRC and the dampening role played by the officials-rank standard in shaping the climate for innovation. However, tracing the causality of incentives—which function on an individual basis—to macro-level data is inexact. Further research into the manner in which individual inventors, scientists and entrepreneurs respond to the described incentive structure is necessary to tighten up the link between micro and macro outcomes. Additionally, the results of this article suggest that the prevailing framework for explaining national innovation rates—the NIS—is insufficient for explaining China's failure to produce frontier innovation on a large scale and that a fuller explanation requires the inclusion of domestic socio-cultural factors and the incentive structure facing inventors, scientists and entrepreneurs.

Besides their relevance to NIS scholarship, this article's results hold implications for the East Asian developmental state literature.[84] In *Betting on Biotech*, Joseph Wong studies three cases—South Korea, Taiwan and Singapore—in which the state attempted, in distinct ways, to promote frontier innovation in the biotechnology sector.[85] Wong finds that the state apparatus that was effective in industrial upgrading is ill-suited to making decisions that involve industries operating on the leading edge of

[79]The vast majority of Chinese state-employed researchers, scholars and teachers are considered, promoted, paid and otherwise treated as civil servants of various ranks.

[80]See note 39.

[81]See note 76.

[82]See note 67.

[83]See note 42.

[84]We are grateful to an anonymous referee for pointing out this connection.

[85]Joseph Wong, *Betting on Biotech: Innovation and the Limits of Asia's Developmental State* (Ithaca, NY: Cornell University Press, 2011).

knowledge. The difference, contends Wong, between the successful intervention of the East Asian developmental state during the catch-up phase and the attempt to foster an innovative biotech sector rests in the fundamental uncertainty associated with frontier innovation.

Wong's argument, that the post-war East Asian developmental state is ineffective in interfacing with 'science-based industries' due to the high degree of uncertainty that is characteristic of such industries, appears to present a plausible rival hypothesis to the one advanced here.[86] That is, if state-led attempts to promote innovation were, in a general sense, futile due to the incapacity of incumbent state institutions to manage uncertainty, the argument, that ill-structured incentives and the officials-rank standard are the primary determinants of the PRC's inability to stimulate frontier innovation, may suffer. However, these proposed explanations are mutually compatible and indeed complimentary. At the center of both explanations is the fundamental distinctness of science-based industries and the state's trouble in adapting to these idiosyncratic features. In the case of China, the state has attempted to set quotas and provide direct financial rewards for processes that often proceed stochastically and are relatively insensitive to extrinsic rewards. In Wong's account, the application of policies and institutions appropriate for industrial development to an emerging science-based industry forced the governments in question to fundamentally modify their developmental state model, scramble to change regulations and manage public sentiment in the face of the disappointing returns to high levels of public investment. Thus, in both cases, the state's failure rests in a misapplication of policy based on a failure to understanding the distinctive character of knowledge-based industries.

Additionally, this article's findings have relevance to scholarship on the middle-income trap and China's prospects for sustaining its rapid economic growth. Stemming from a 2007 World Bank report observing that middle-income countries were often outperformed by low- and high-income countries in terms of GDP growth, the middle-income trap refers to a hypothesized period of low-growth equilibrium that follows a country's assent from low-income status.[87] While the proposed mechanisms underlying the middle-income trap are manifold, the portion of the theory most relevant to this article's findings relates to the ambivalent status of middle-income countries in the global production chain. No longer able to compete with low-income countries based on labor cost and not yet holding a comparative advantage vis-à-vis advanced economies in technology-intensive industries, middle-income countries have no obvious solution to sustaining high rates of growth. The CCP's solution to this prospect has been unequivocal: attempt to develop the indigenous innovation capacity to compete with advanced economies on the technological frontier. However, this article's findings suggest that these policies face at least two significant structural impediments. First, the devised incentive structure is ill-suited to knowledge-based sectors. Second, the continued influence of the officials-rank standard appears to be crowding out real innovation.

There are several policy-relevant insights that can be drawn from the preceding analysis. While Breznitz and Murphree argue that its current innovation profile may be sufficient for China to become a world economic leader, chronic technological laggard status would guarantee the PRC's continued reliance on countries at the innovative frontier.[88] Besides the profound geopolitical consequences associated with such circumstances, this article contends that should the present conditions persist, China's economic growth will suffer. In order to move towards large-scale real innovation, the influence of the CCP in universities and firms must lessen. The results of this article suggest that direct financial incentives have been associated with increased nominal patenting and publishing rather than increased genuine innovation. Fiscal incentives such as tax breaks may be preferable to direct financial incentives in promoting innovation because the potential of such measures to create distortions by selecting winning industries is less than in direct funding schemes. While measures recently undertaken by the

[86]*Ibid*., p. 2.

[87]Indermit Singh Gill, Homi J. Kharas and Deepak Bhattasali, *An East Asian Renaissance: Ideas for Economic Growth* (Washington, DC: World Bank Publications, 2007).

[88]Dan Breznitz and Michael Murphree, *Run of the Red Queen: Government, Innovation, Globalization, and Economic Growth in China* (New Haven, CT: Yale University Press, 2011).

China Association for Science and Technology (CAST) to eliminate fraud from academic publications are a positive step, academic corruption is largely a function of the pronounced and ubiquitous role of the state in the research system.

Ultimately, increased openness and exposure to alternative perspectives regarding the role of the state may erode the place of the officials-rank standard in the Chinese NIS. However, the officials-rank standard is a critical mechanism by which the CCP maintains power and thus challenges to this feature will be resisted. Fundamental socio-political reform, therefore, seems to be necessary for China to become a large-scale producer of frontier innovation.

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Notes on contributors

Jon Schmid is a Ph.D. student in the Science, Technology and International Affairs program in the Sam Nunn School of International Affairs at the Georgia Institute of Technology (Georgia Tech). Jon is a Georgia Tech Presidential Fellow, a Coca-Cola Fellow and a Sam Nunn Security Fellow. He conducts research on the determinants of national innovative productivity, economic development and international political economy.

Fei-Ling Wang is a professor at the Sam Nunn School of International Affairs, Georgia Institute of Technology and a member of the Council on Foreign Relations. He has published six books (two co-edited) and over 70 book chapters and articles. He is currently working on a book on the rise of China.

ORCiD

Jon Schmid http://orcid.org/0000-0002-2317-8966