Title

China's Push for Precision Medicine: Lessons for Science and Industrial Policies

Author

Au, Larry

Publication Date

2023-09-27

Data Availability

The data associated with this publication are within the manuscript.

Peer reviewed

UC INSTITUTE ON GLOBAL CONFLICT AND COOPERATION

WORKING PAPER NO. 15
SEPTEMBER 2023

China’s Push for Precision Medicine: Lessons for Science and Industrial Policies

Larry Au

Abstract

Precision medicine was included in China’s 13th Five-Year Plan (2016–2020) as a strategic emerging industry. Drawing primarily on bibliometric analysis of scientific publications on Web of Science and the Chinese National Knowledge Infrastructure databases, I examine trends in publications, multi-country collaboration networks, sources of funding, and influential institutions in precision medicine. Through this mapping of the precision medicine field in China, this paper discusses the role of the Chinese state as well as the U.S.-China relationship in fostering research around precision medicine in China. The analysis identifies the diversity of state funding forces, the strength and centrality of U.S.-China scientific collaborations, and the widespread popularity of precision medicine in China. It ends with brief lessons that we can draw from the example of precision medicine in China for science and industrial policies.

Keywords: Precision medicine, genomics, U.S.-China cooperation, science policy

This working paper is part of an IGCC series on China’s science, technology, innovation and industrial policies. This work was made possible through support from the U.S. Department of State’s Bureau of Intelligence and Research.

Author

Larry Au
Assistant Professor, City College of New York
Email: lau2@ccny.cuny.edu

Suggested Citation

Au, Larry. 2023. *China’s Push for Precision Medicine: Lessons for Science and Industrial Policies*. IGCC Working Paper No 15.
escholarship.org/uc/item/2vc52690

1. Introduction

Precision medicine—as a scientific project and as a policy idea—has been taken up by scientists and policymakers around the world in the past decade (Prainsack 2020; Blasimme and Vayena 2016; Eyal et al. 2019; Au 2021). The term was coined by experts convened by the U.S. National Research Council in their report *Towards Precision Medicine: Building a Knowledge Network for Biomedical Research and a New Taxonomy of Disease* (2011). The definition of precision medicine in the report is as follows:

> "'Precision medicine' refers to the tailoring of medical treatment to the individual characteristics of each patient. It does not literally mean the creation of drugs or medical devices that are unique to a patient, but rather the ability to classify individuals into subpopulations that differ in their susceptibility to a particular disease, in the biology and/or prognosis of those diseases they may develop, or in their response to a specific treatment. Preventive or therapeutic interventions can then be concentrated on those who will benefit, sparing expense and side effects for those who will not" (125).

In short, precision medicine aims to provide better medical care and improve health outcomes by incorporating new forms of big data such as genomics into clinical decision-making. For instance, with the declining costs of genetic testing, there is the hope that these new tools can help us better diagnose and prescribe appropriate medications matched to a patient's genetic profile. Aside from the publication of this report, precision medicine received high-level backing in the United States, after the Obama administration's launch of the Precision Medicine Initiative in 2015, which launched the All of Us Research Project that sought to amass over one million genomes in the United States for a longitudinal study of health outcomes in the U.S. population. Precision medicine is beginning to make an impact in the care and treatment of certain types of cancer, but for the most part, the promise of precision medicine is yet to be realized and we are only in the beginning stages of long-term transformations in healthcare and the biomedical sciences.

The idea of precision medicine was also taken up enthusiastically in China.
The diffusion of the concept occurred largely via elite scientific networks: at scientific conferences, through widely circulated and popularized journal articles, mentor-mentee and collaborator relationships amongst scientists in the United States, increased knowledge in genomics,[1] and the declining costs of whole genome

1 See for instance the first-person accounts by Yu (2017) at the China Academy of Sciences and Olson (2017) one of the drafters of the NRC precision medicine report, published in Genomics, Proteomics & Bioinformatics. The two recount how the term precision medicine came about and how Chinese scientists were excited by this new idea through informal exchanges.

sequencing.[2] The term precision medicine was included in the 13th Five-Year Plan (2016–2020), as well as the Healthy China 2030 Plan (健康中国, jian kang zhong guo), which states,

> "Strengthen breakthroughs in key technologies such as chronic disease prevention and control, precision medicine, and smart medicine, and focus on the deployment of innovative drug development, localization of medical devices, and modernization of Chinese medicine. Significantly enhance the scientific and technological support capabilities for the prevention and treatment of major diseases and the development of the health industry. Strive to have the influence of scientific papers and the total number of patents in the forefront of the world by 2030."[3]

Alongside these other biomedical innovations, precision medicine was imagined to help alleviate the burdens brought on by urbanization and an aging society.[4] Precision medicine became a site where U.S.-China cooperation and competition could unfold. During the state visit by Xi Jinping to the United States in 2015, precision medicine was listed amongst the items of further cooperation in the outcomes list.[5] Yet, as stated in the above quote, precision medicine along with other investments in biotechnology, were meant to help position China as a leader in global science, dethroning the U.S. scientific dominance.

The purpose of this paper is to describe and sketch out the terrain of precision medicine in China and to figure out (1) who the major actors are, (2) who funds it, and (3) how potential U.S.-China decoupling in science can jeopardize the nascent field. I focus primarily on bibliometric analysis of scientific publications to get a handle of the contours of this field. At the end, I discuss how care needs to be taken in managing U.S.-China geopolitical tensions so that the gains brought about by scientific collaboration in precision medicine are not sacrificed. I will also discuss what lessons the case of precision medicine has to offer for policymakers interested in science and industrial policy.

---

2 There is a longer history of precision medicine in its ties to genomics and China's participation in the Human Genome Project (see for example, Au and da Silva 2021).

3 Chinese text: http://www.gov.cn/zhengce/2016-10/25/content_5124174.htm

4 Some proponents of precision medicine have also sought to carve a space for traditional Chinese medicine to take advantage of the push and momentum in precision medicine, arguing that the two share affinities in the individualized approaches to health.

5 Outcomes list: http://www.chinadaily.com.cn/world/2015xivisitus/2015-09/26/content_21988239_4.htm

2. Precision Medicine in China

The rapid ascent of precision medicine as a scientific project and policy idea in China can be attributed to three factors: (1) the recruitment of overseas and returnee scientific talent; (2) a favorable policy environment for biotechnology; and (3) the ability of scientists to amass large quantities of genomic data necessary to make better predictions about health outcomes. In this section, I will provide a brief background to how these factors have enabled Chinese scientists to position precision medicine as a tool that can help solve the problems facing the Chinese state and encourage further investments in this sector.

First, China's precision medicine push has benefited enormously from the return of overseas educated and trained scientists, from the United States, United Kingdom, Europe, Australia, Canada, and elsewhere. Amid worries about "brain drain," Chinese policymakers have crafted programs to look at the "diaspora option" to bring back scientific and entrepreneurial talent to China (Zweig, Fung, and Han 2008; Zweig, Changgui, and Rosen 2004). In recent years, the life sciences is one area where top-level talent programs, such as the Thousand Talents Program, have recruited heavily, offering incentives for early career and senior scientists to return to China to conduct their research (Cao 2017). Part of the hope here is also to increase the productivity and quality of scientific research conducted at China's universities. Despite the plethora of state-run programs aimed at talent recruitment, this return of overseas talent to China need not be nefarious. In interviews with scientists interested in advancing precision medicine within China, many articulated personal, professional, and scientific reasons for returning to China (Au 2020; see also, Paul 2021). For instance, precision medicine scientists opined that one reason they decided to uproot their lives and return to China to establish their careers is because of their interest in studying the link between genetic mutations and health outcomes in Chinese populations—something that is harder to do overseas because of smaller numbers of individuals of Chinese ancestry in places like the United States and Europe. But interview respondents have also recounted experiences of direct recruitment through the talent programs and the added benefits of monetary rewards and research funding in shaping their decision of return migration.

Second, the favorable policy environment for biotechnology in recent years has also enabled proponents of precision medicine in China to benefit from increased investments, grantmaking, and accommodations given to the sector. This favorable policy environment hinges on decades of experimentation and reform in "science capacity, science-industry linkages, and state regulatory regimes" (Zhou and Coplin 2022, p. 64). China's science and technology policy learned from models in the United States blur the boundaries between science, industry, and the state (Murray 2010; Berman 2011). Since the 1990s and early 2000s, reform of China's national innovation system has focused on the reorientation of the hierarchical structures of Chinese scientific research to promote university-industry linkages, which aims to inject a sense of market competition and entrepreneurialism among China's researchers (Xiwei and Xiangdong 2007; Cao, Suttmeier, and Simon 2006). This need to balance traditional technonationalist concerns of the state with the need to sustain dynamic global scientific networks and capital flows has also been described as "networked techno-nationalism" (Ibata-Arens 2019). These broader dynamics have resulted in hybrids and chimera-like organizational forms (Coplin 2019) and worries from scientists about the need for boundary repair (Ma 2019). Nonetheless, proponents of precision medicine have been able to take advantage of these developments to advance their goals: from yoking together university-hospital-industry collaborations, capitalizing on state support in this sector, while drawing on knowledge and technologies from global scientific networks.

Third, as mentioned earlier, scientists' reasons for returning are manifold, but one of the perceived advantages of precision medicine in China is the relative ease in which genetic data can be amassed. For instance, in interviews, precision medicine scientists point to the prevalence of diseases that affect Chinese populations that are rarer outside of China, the concentration of patients in large hospitals organized around specific diseases, and beliefs about the willingness of Chinese patients to participate in research studies (Au 2020). Part of this reflects cultural beliefs about "Chinese DNA" and the need to identify, protect, and exploit this reservoir of data (Sung 2010). BGI, the genomics sequencing powerhouse that manages the state-backed National GeneBank, is well known for its global aspirations and its self-proclaimed mission of creating science that benefits humanity (Stevens 2018; Ong 2016; Coplin 2019). But the process of amassing this data is also fraught with politicking, negotiation, and conflict, as scientist/entrepreneurs position themselves to act in service and on behalf of the state (Coplin 2019). Bioethicists have also noted the fragmented and contentious practices of biobanking that makes centralization of data and its international portability particularly vexing, resulting in data silos that have yet to be connected together (Sleeboom-Faulkner, Chen, and Rosemann 2018; Wahlberg et al. 2013).

These tensions between the global and the national have manifested more recently in the securitization of biological materials under China's "techno-security state" (Cheung 2022). Recent biosafety and biosecurity laws and regulations have made the sharing of genetic data with international collaborators particularly difficult (Cao 2021). Specifically with precision medicine, such a turn toward securitization has interrupted and put a pause on the freer flow of data that had facilitated international collaborations in years prior.

In sum, precision medicine's rapid ascent as a policy idea and scientific project in China can be attributed to factors that are both within and beyond the control of the Chinese state. Certainly, without state intervention and support, precision medicine's rise would not have been as rapid. Funding sources would have been scanter, returnees would have been less incentivized to come back without clear career pathways, and the mass collection of biological data would not have been as easy. Nonetheless, as this brief review hopefully begins to suggest, the growth of scientific publications in the field of precision medicine in China relies on social and economic processes inside and beyond China.

3. Data and Methods

The following section draws on bibliometric analysis of scientific publications from two databases. *First*, I primarily rely on publications indexed in the Web of Science (WoS) database. For the most part, WoS indexed journals have higher impact factors and are written in English. WoS is typically used in bibliometric analysis because of the quality of journals indexed there. Using the term "precision medicine," English-language journal articles were retrieved if the article contained the term in the title, abstract, or keywords. This yielded 4,599 articles up to the end of 2019. For this analysis of WoS articles, I show the number of U.S.-China ties within these collaboration networks. Network visualizations were using the *bibliometrix* packages in R (Aria and Cuccurullo 2017). I then examine the types of China-based funders for articles published about precision medicine. I then study a subsample of 633 articles with authors located within China to focus on the types of institutions that authors are most frequently affiliated with.

Second, I draw on a more cursory analysis of publications in the Chinese National Knowledge Infrastructure (CNKI) database. The CNKI data typically capture journals that have lower impact factors, are based in China, and are written in Chinese. Access to CNKI may in the future also be more restricted due to recent controversies.[6] CNKI is the state-backed database and indexing of Chinese academic journals (discussed further in section 4.2). A search using "precision medicine" as the keyword yielded 3,231 entries up to December 31, 2019. There is some noise in the CNKI results with science "news sites" included in the count of "journal" articles. The graphs were visualized using the in-built visualization functions on CNKI's website. Brief observations are included in the next section. The inclusion of CNKI data provides a second point of reference to trends observed in WoS.

There are of course limitations to using bibliometric data.[7] For instance, there is considerable heterogeneity in the types of publications listed even when restricted to research articles: medical case reports, medical protocols, lab studies, genome-wide association studies (GWAS), systematic reviews, etc. The quantity of publications (the measure largely used in the next section) is thus not the most accurate measure of the influence that a particular country, institution, or author group has on the scientific field. Publication and citational practices also differ across publications, specialties, and subfields (e.g., some fields can publish a lot by writing case reports or prospective cohort studies of a handful of patients). Future studies should examine patenting activities to get a handle on whether precision medicine in China is starting to impact industrial and commercial practices. But, as much of precision medicine remains on the "science" side of the science-clinical spectrum, bibliometric data is still useful for sketching out the landscape of precision medicine in China.

6 Recent controversies relate to sensitive information being accessed by foreigners through CNKI, which has prompted the Cyberspace Administration to rethink access to the private company's database: https://www.scmp.com/tech/big-tech/article/3183008/chinas-internet-watchdog-launches-cybersecurity-investigation

7 I supplement my interpretation of this brief bibliometric analysis with my understanding of precision medicine through fieldwork conducted in China between 2016 and 2019 with interviews with Chinese scientists, about 80, in this emerging field and with observations of about 20 scientific conferences related to precision medicine. Lessons learned from these other types of data are sprinkled in the text and in the footnotes.

4. Findings

4.1 Precision Medicine Publications in WoS

Globally, between 2012 and 2019, there were some 4,599 articles related to precision medicine in WoS. Again, articles in WoS are typically in higher-impact journals and are published in the English language. In these articles, 2,611 contained articles with first authors in the United States and 633 contained articles with first authors in China. In this section, I describe the publication trends during this time period, provide network visualizations of multi-country collaborations and describe China's position in these networks and its relationship to the United States, and discuss the major funders and institutional affiliations of published precision medicine authors.

Figure 1: Growth of Publications in Precision Medicine Globally, in the United States and China

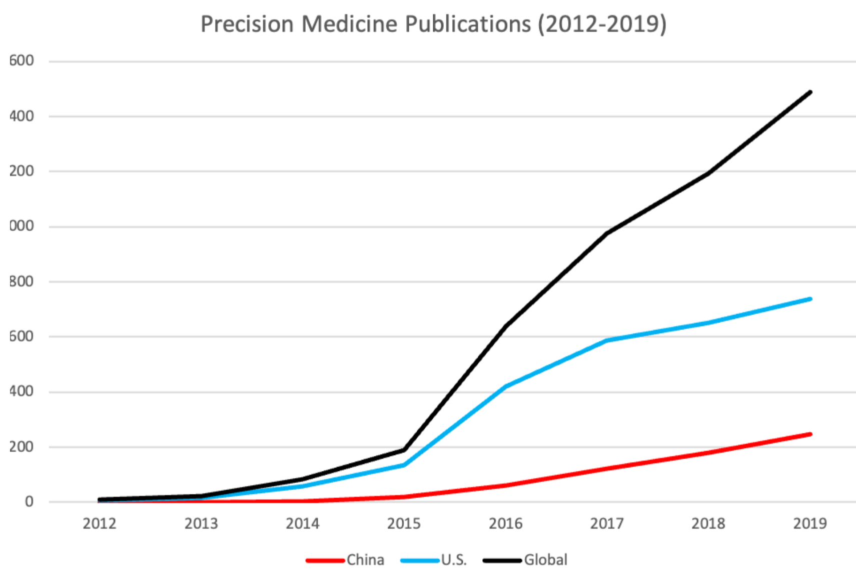
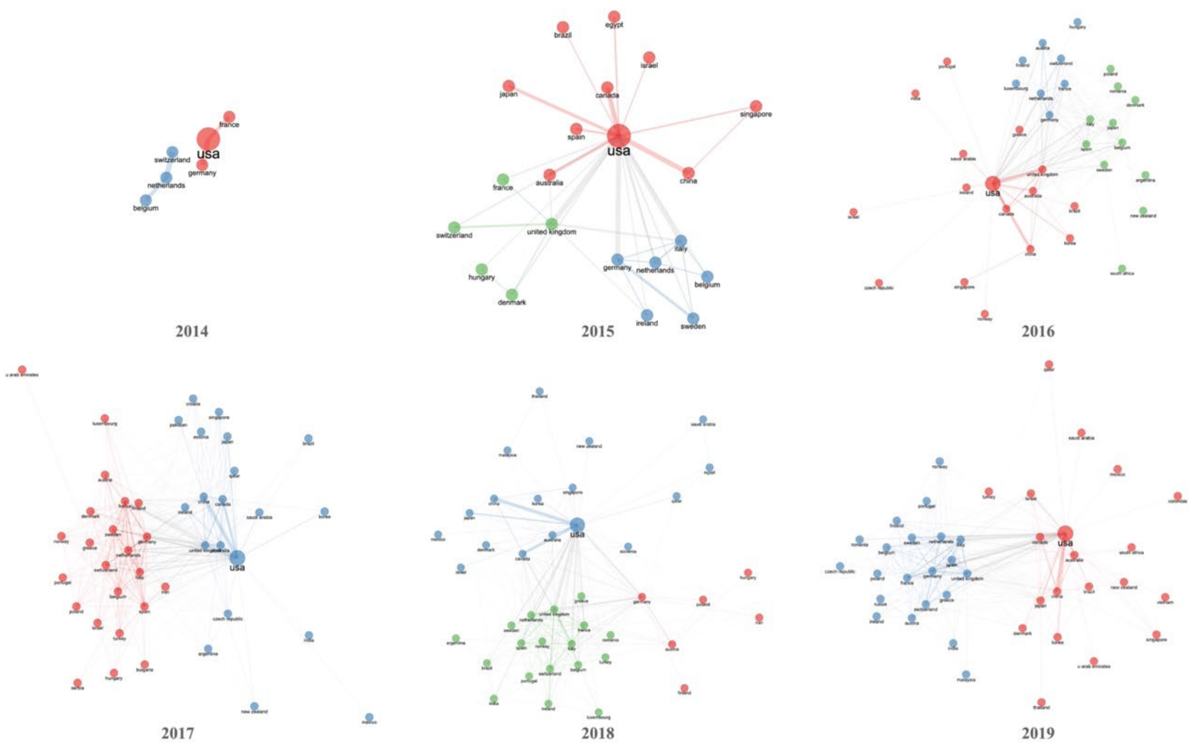


Figure 1 depicts the yearly trends globally, in the United States, and in China. When compared to other similar labels and trends in biomedicine (e.g., evidence-based medicine, translational medicine, genomic medicine), precision medicine has displayed characteristics of being field disrupting because of its insurgence potential, due to its rapid adoption from the time the slogan first appearing in 2012 (discussed more in detail in Au 2021). While China's publication trends mimic and respond to what is being done in the United States and globally, it is worth noting here that the growth of publications is particularly high in China. For instance, between 2019 and 2018 in China, publications grew by 37 percent, while in the same time period in the United States, there was only a growth of 13 percent.

For 2018 and 2017, in China publications grew by 47 percent, and in the United States for the same period, there was only a growth of 11 percent. This points to, perhaps, the potential for China to "catch up" to the United States in the future if it keeps up with its current momentum and growth rates.[8] This is one of the stated goals in the Healthy China 2030 plan and in other documents, which aims to see China's scientific productivity in the life sciences take the global lead by the end of this decade.[9]

Figure 2: Top 50 Countries Collaboration Networks from 2014 to 2019 in Precision Medicine



Drawing on the full set of records from WoS for precision medicine publications, **Figure 2** depicts the country collaboration networks from 2014 to 2019. Each network diagram depicts the top 50 country collaborations of that year. A multi-country collaboration—or when authors of different countries collaborate and appear listed in a publication—here is represented by a tie between two country nodes. The relative size of the node represents the number of papers published by authors belonging to that country.

8 Data from 2020 and 2021 shows that despite the pandemic, and the effect that COVID-19 has had with reorienting the research activities of scientists, publications in precision medicine continue to grow. For China, in 2020 there were 283 publications (compared to 247 in 2019), and in 2021 there were 373 publications. For the United States, in 2020 there were 757 publications (compared to 737 in 2019), and in 2021 there were 832 publications. Globally, in 2020 there were 1680 publications (compared to 1489 in 2019), and in 2021 there were 1978 publications.

9 Of course, quantity does not equal to quality. For the most part, from my other bibliometric analysis performed elsewhere (Au 2021), the "key concept" and influential papers in most fields such as precision medicine tend to come from U.S.- or European-based researchers.

We can say three things from these visualizations. *First*, from these network diagrams, we can see that the United States plays a central and prominent role in promoting precision medicine throughout this time period. This tracks with the origins of precision medicine as a term in the United States, but is also influenced by the preference of other labels such as "stratified medicine" in the United Kingdom, "personalized medicine" in Europe, and "genomic medicine" in other quarters. Precision medicine is also typically labeled as a "U.S. idea" by Chinese scientists. *Second*, China emerges as an international collaborator with scientists in Singapore and more prominently, with the United States, in 2015. While Chinese scientists develop ties with researchers elsewhere, such as with Australia, the United Kingdom, and Sweden in 2016, and with Saudi Arabia, Pakistan, Qatar, South Korea, Ireland, and other places by 2017, China remains squarely within the U.S.-centered cluster of precision medicine research in the network diagrams throughout this period. *Third*, as indicated by the thickness of ties between the U.S. and China nodes, the collaborative relationship between these two countries are perhaps the strongest and most repeated out of all other dyadic relationships depicted in the network diagrams. This points to the willingness of scientists from the United States and China to collaborate up until 2019.

From **Table 1**, we see the top funders from China for precision medicine research for the full set of publications listed in WoS.[10] We can learn three things from this list of funders. First, while there are precision-medicine-specific sources of funding (e.g., Precision Medicine Initiative of the National Key Research and Development Plan), most of the funding sources come from more general purpose sources for basic science research (e.g., National Natural Science Foundation of China), technology research and development (e.g., National Key Research and Development Program), higher education funds (e.g., Fundamental Research Funds for the Central Universities), and scholarship and talent programs (e.g., China Postdoctoral Science Foundation). This reflects the ability of precision medicine researchers to draw on the favorable policy environment for biotechnology that has given to multiple sources of funding for their work. Second, in addition to national sources of funding, precision medicine researchers have been able to mobilize provincial (e.g., National Natural Science Foundation of Guangdong Province), municipal (e.g., Beijing Municipal Science Technology Commission), and university funding sources (e.g., China Academy of Sciences). This also points to the potential for competing local agendas in precision medicine, as well as the use of local policy experimentation before the setting of a national standard for precision medicine (Greenhalgh 2008). Third, the geographic diversity of funding sources is also of note: showing clusters of precision medicine research activity in places beyond Beijing, Shanghai, and Shenzhen, such as in Jiangsu, Chongqing, Jilin, Zhejiang, and Henan. Not shown in this list, however, are the numerous foreign sources of funding that precision

10 This table reflects manual curation to merge different spellings and translations of these funding sources. Funders with more than 10 papers published were included.

medicine scientists also draw on and benefit indirectly from, such as collaborations with researchers with funding from the U.S. National Institutes of Health (which funded over 89 papers in the China subsample) and biotech companies such as Merck (which funded 3 papers in the China subsample).

Table 1: Top 20 China Funders of Precision Medicine Research (in WoS)

Region	Funder	Articles
National	National Natural Science Foundation of China (NSFC)	835
National	National Key Research and Development Program of China (863 Program)	177
National	Precision Medicine Initiative of the National Key Research and Development Plan of China	105
National	National Basic Research Program of China (973 Program)	37
National	Fundamental Research Funds for the Central Universities	30
National	China Postdoctoral Science Foundation	46
University	Chinese Academy of Sciences	46
Provincial	National Natural Science Foundation of Guangdong Province	42
Municipal	Beijing Municipal Science Technology Commission	30
National	Ministry Of Science and Technology China	30
Provincial	Natural Science Foundation of Jiangsu Province	26
National	China Scholarship Council	25
Municipal	Natural Science Foundation of Shanghai	23
University	Beijing Lab for Cardiovascular Precision Medicine Beijing China	39
Municipal	Beijing Natural Science Foundation	20
University	Key Laboratory of Shaanxi Province for Craniofacial Precision Medicine Research	16
National	China Precision Medicine Initiative	15
National	National Program on Key Research Project of China	15
Provincial	Natural Science Foundation of Zhejiang Province	15
Provincial	Science and Technology Innovation Talents Support Plan of Henan Province	15

Finally, looking at **Table 2**, we can see the institutions with more than 10 papers published that authors in the China subsample were affiliated with. From this list, we can observe a few things. First, at the top of the list, we see the dominance of researchers from the Chinese Academy of Sciences (CAS), with more than double of the number of publications from the next university, Shanghai Jiao Tong University. This reflects somewhat the hierarchy of scientific research within China. Second, beyond the entries at the top of the list, which clusters in Beijing, Shanghai, and Guangzhou, there is a wide range of cities in which researchers are active in precision medicine. As previously mentioned, this can reflect both the local policy experimentations with precision medicine, as well as the wide range of institutions and scientists within China that have hopped aboard the precision medicine bandwagon.

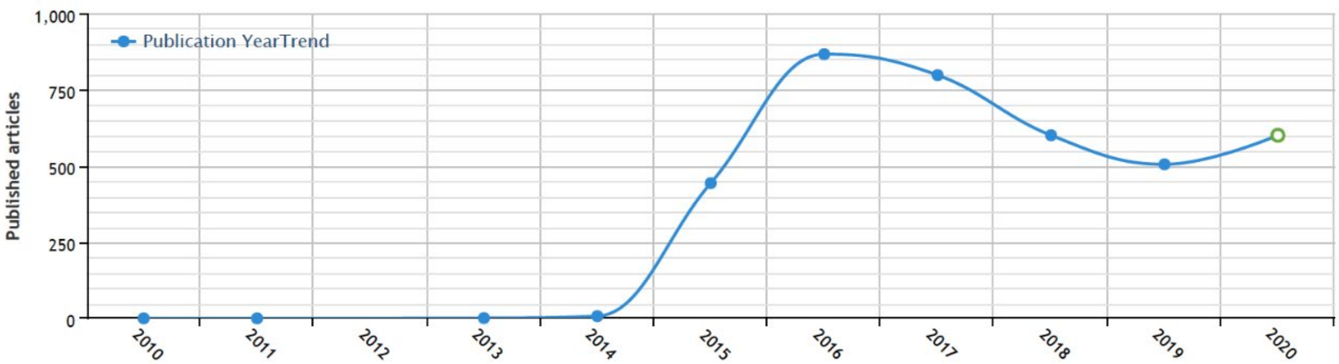
Table 2: Top 20 Institutional Affiliations in China Subsample (in WoS)

City	University	Articles
Beijing	Chinese Academy of Sciences	117
Shanghai	Shanghai Jiao Tong University	56
Beijing	Chinese Academy of Medical Sciences/Peking Union Medical College	49
Shanghai	Fudan University	45
Hangzhou	Zhejiang University	32
Guangzhou	Sun Yat Sen University	31
Beijing	Peking University	29
Beijing	Capital Medical University	28
Shanghai	Shanghai Institutes for Biological Sciences CAS	24
Changsha	Central South University	23
Beijing	Tsinghua University	18
Huangzhou	Huazhong University of Science Technology	16
Chengdu	Sichuan University	16
Harbin	Harbin Medical University	15
Guangdong	Southern Medical University	15
Tianjin	Tianjin Medical University	15
Nanjing	Southeast University China	14
Nanjing	Nanjing Medical University	13
Shanghai	Tongji University	12
Xiamen	Xiamen University	12

4.2 Precision Medicine Publications in CNKI

As mentioned previously, CNKI typically includes scientific journals and other types of publications based in China. Many of these publications are published in the Chinese language. Between 2012 and 2019, the term *precision medicine* (and its Chinese language equivalent, 精准医疗) yielded 3,231 entries.[11] The point of including CNKI data is to give a second point of reference for the trends discussed earlier. As such, the presentation of findings here will be briefer than the discussion of WoS data.

Figure 3: Publications Over Time (in CNKI)



First, the publication trend seen in **Figure 3** largely shows the same uptick around 2015 and 2016 that was observed in the previous section.[12] This perhaps better reflects the reaction of Chinese scientists to the Obama administration's launch of the U.S. Precision Medicine Initiative, something that Chinese scientists cited in interviews as a pivotal event for their decision to enter into the field. But what is also of note here in the CNKI data is the fall from 2017 to 2019 in the number of precision medicine publications. While we can only speculate, we could possibly attribute this to a slight sobering of the hype surrounding precision medicine initially. Additionally, the term precision medicine has also, in recent years, fallen out of fashion, perhaps due to its perceptions as a "U.S. idea." Other terms such as digital health (数字健康, shu zi jian kang), Internet hospitals (互联网医院, hu lia wang yi yuan), and artificial intelligence healthcare (人工智能医疗保健, ren gong zhi neng yi liao bao jian) have also become more popularized in recent years.

11 The preferred term and translation for precision medicine is 精准医疗 (jing zhun yi liao), which translates roughly to precision medicine therapies. This is preferred over 精准医学 (jing zhun yi xue) which translates somewhat closer to the discipline or scientific study of precision medicine. The thinking, from interviews, is that the former term is better able to convey the clinical aspirations of precision medicine.

12 The 2020 number is only projected on this graph.

One potential explanation for the continued increase in publications in precision medicine as a label in WoS by Chinese scientists is perhaps a result of the need to continue to use this term in their engagement with global science and international audiences, while pivoting to other terminology domestically.

Second, of papers with listed funders seen in **Table 3**, the top ten funders are as follows: National Natural Science Foundation of China (NSFC), National Basic Research Program (Program 973), National Science and Technology Support Program, State High-Tech Development Plan (863 Program), Beijing Municipal Natural Science Foundation, National Social Science Fund of China, Shandong Province Natural Science Foundation, Beijing Municipal Science & Technology Commission, Jiangsu Province Natural Science Foundation, and Shanghai Municipal Science & Technology Commission. This reflects the trends that we observed previously in WoS, with the mix of national, provincial, and municipal sources of funding, as well as the dominance of NSFC funding. Also notable here and with the WoS data is that the vast majority of funders are affiliated with science and technology funding (e.g., Ministry of Science and Technology) rather than health policy (e.g., National Health Commission or its predecessor the National Health and Family Planning Commission), as one would think for a health-related research program. This too reflects the fact that precision medicine is still largely a research program rooted in basic science and technological development, rather than being integrated widely in clinical settings.

Table 3: Top 10 Funders (in CNKI)

Region	Funder	Articles
National	National Natural Science Foundation of China (NSFC)	259
National	National Basic Research Program of China (973 Program)	27
National	National Science and Technology Support Program	15
National	State High-Tech Development Plan (863 Program)	15
Municipal	Beijing Municipal Natural Science Foundation	14
National	National Social Science Fund of China	7
Provincial	Shandong Province Natural Science Foundation	7
Municipal	Beijing Municipal Science & Technology Commission	7
Provincial	Jiangsu Province Natural Science Foundation	6
Municipal	Shanghai Municipal Science & Technology Commission	5

Third, the distribution of institutions is again more diverse than one would expect. As mentioned previously, a common critique levied by Chinese scientists is the “hierarchical” system of research that privileges institutions such as CAS, Peking University, and Tsinghua University above all others, making research funding easier to come by for researchers located there when compared to other institutions. As seen in **Table 4**, the top 10 institutions contributing to CNKI precision medicine publications include the following: Peking University, Fudan University, West China Hospital of Sichuan University, People’s Liberation Army General Hospital, Chinese Academy of Medical Science Peking Union Medical College, Zhejiang University, Tsinghua University, Beijing University of Chinese Medicine, Shanghai Jiatong University, Institute of Medical Information/Medical Library of the CAMS/PUMC. The dominance of CAS is much less pronounced here than the WoS data. This perhaps also reflects the ability of CAS researchers to publish in overseas journals with higher impact factors listed in WoS compared to publications in CNKI.

Table 4: Top 10 Institutional Affiliations (in CNKI)

City	University	Articles
Beijing	Peking University	47
Shanghai	Fudan University	42
Chengdu	West China Hospital of Sichuan University	27
Beijing	People’s Liberation Army General Hospital	24
Beijing	Chinese Academy of Medical Science Peking Union Medical College	23
Hangzhou	Zhejiang University	19
Beijing	Tsinghua University	18
Beijing	Beijing University of Chinese Medicine	18
Shanghai	Shanghai Jiatong University	18
Beijing	Institute of Medical Information/Medical Library of the CAMS/PUMC	17

In sum, this second batch of bibliometrics from CNKI helps confirm some of the trends that we observed in the WoS data: the upward trajectory of precision medicine publications starting from 2015/2016 in response to the U.S. announcements, the range of science funding from a wide variety of state sources, and the geographic reach of precision medicine research in China. Because of the differences between publications in CNKI and WoS, we also have observed some differences in the downturn of precision medicine publications in 2017–2019 and the greater diversity of institutional affiliations.

5. Discussion

In this paper, I presented results from a cursory bibliometric analysis of precision medicine from China to begin to map out some of the key institutions, funders, multi-country collaboration networks, and publication trends in the field. As I show, precision medicine's rise in China does predate the high-level push from the state with its inclusion in the 13th Five Year Plan, reflecting perhaps the behind-the-scenes lobbying of scientists for its inclusion in key national plans and the willingness of policymakers to heed their demands.[13] This dance between scientists, entrepreneurs, and the state has been described as attempts by Chinese scientists and entrepreneurs eager to "compete for government recognition" (Zhang and Burton 2022, p. 48), who must perform their worth through being of service to and acting on behalf of the state (Coplin at this conference). At other times, the boundaries of permissibility is particularly porous and blurry in moments of controversies, with experts and public opinion in mind, in order to not impugn on the credibility and legitimacy of state power (Lei 2021; Cao 2018; Coplin 2019). Scientific strategies and research programs, such as precision medicine, should also be understood in this vein—as a negotiating tactic by scientists in order to demonstrate their continuing relevance to the state and the public.[14]

Additionally, through the bibliometric analysis, we see the centrality and closeness of the U.S.-China relationship in the field of precision medicine prior to 2019, through the network visualizations. Future work will need to be done to assess the effect that tightening data regulations, increased scrutiny of international scientific collaborations (both within China and in the United States), and political sensitivities around biological and genetic research will have on precision medicine and similar scientific fields. The U.S.-China relationship has been productive: It has aligned research agendas between the two countries, enabling researchers to speak to one another, collaborate, and make use of funding sources and data in both countries.

13 The State Key Laboratory for Genomic and Precision Medicine at the China Academy of Sciences renamed their laboratory to include the phrase precision medicine in 2012 in lockstep with the announcement of the National Research Council (2011) report.

14 In interviews, when asked to "justify" the relevance of precision medicine to China, precision medicine scientists frequently point to the changing demographics of an aging China that has made chronic illnesses and certain types of cancers more prevalent—diseases that precision medicine is theoretically well positioned to make an impact in. Precision medicine here is seen as a tool that can help ameliorate the social and demographic changes of an aging and urbanizing China. Additionally, respondents also point to the potential for precision medicine to help spur innovation and economic growth in the biotech sectors, as well as the ability of scientists in this field to become global leaders and overtake the United States in technonationalist competitions over scientific supremacy (Au 2020). This most certainly speaks to the broader cultural power of science within China, which has been described as "scientism" and "technicism," or the belief in the ability that science and technology can solve broader social problems in China (Greenhalgh and Zhang 2020). Precision medicine, in many ways, is imagined to be a tool in solving these social, economic, and political problems.

With the analysis of funding sources in China, we can see the wide range of state funding sources that scientists in China have taken advantage of: national, provincial, and municipal-level funding agencies. We also see that the majority of funders tend to focus on scientific research and technology development, rather than health-related matters. This points to the current emphasis of precision medicine and the crucial role of the Chinese state in sponsoring this nascent field. What is not included in the listed sources, however, is the prominent role of overseas funding sources to the development of precision medicine in China. For instance, at least 10 to 15 percent of articles with a Chinese first author also received funding or indirectly benefited from funding for their international co-authors from the U.S. National Institutes of Health. With the analysis of institutional affiliations in China, we can also see the wide range of universities and hospitals involved in pushing forward precision medicine in China. While the data reflects somewhat the dominance of Beijing, Shanghai, and Shenzhen institutions, there is still a wide range of institutions based in secondary and tertiary cities that host scientists publishing in this field. This again speaks to the willingness of local governments to sponsor precision medicine research in response to the call from the central authorities to invest in this key strategic industry.

There are some lessons for science policy from the case of precision medicine in China. First, as intimated earlier, precision medicine is a uniquely global project imagined by U.S. and Chinese scientists. The story and case of precision medicine's rise in China speaks to the close linkages between these two groups of scientific elites (in many cases, these are collaborator relationships, but also mentor-mentee relationships between Ph.D. and postdoctoral advisors and their former students who have returned to China).[15] Science policy targeted at restricting the flow or recruiting scientific talent needs to thus account for the informal processes of socialization that were crucial in sustaining this global scientific project.

Second, science is slow moving. The trends that we observe in this short period build on the goodwill, credibility, and trust gained by scientific collaborators over the last two to three decades. It also reflects the out and return migration of scientific talent to the U.S. and elsewhere. The ability of Chinese scientists to gain a foothold in the precision medicine field relied on their previous participation and engagement with prior "big science" projects such as the Human Genome Project and 1000 Genomes Project, where they gained competency and credibility in the eyes of the Chinese state.[16] Science policy

15 Recent scrutiny over the renumeration of U.S. scientists in China illustrates how hard capturing some of these ties can be. Of course, bibliometric analysis with attention paid to the longitudinal and changes in institutional affiliations can help shed light on these relationships.

16 Post-Human Genome Project initiatives such as 1000 Genomes Project and the Genome 10K Project are particularly important for Chinese scientists because of the explicit goal of these projects to increase diversity of genetic databases. Chinese scientists have picked up on these efforts to try and decode "Chinese DNA" and increase representation of Chinese individuals in genomic research.

thus needs to think in the longer term, recognizing that technological and clinical innovations take years if not decades to mature.

Third, the current push toward the securitization of biological specimen, research, and technology reflects largely a post-hoc realization of the openness of scientific systems and the potential dangers and threats they pose to national security and economic interests of the Chinese and U.S. state. Precision medicine has the potential to result in life-saving cures and better treatment for Chinese populations. While some Chinese scientists may also buy into technonationalistic framing about the ascendency of Chinese science, many are also motivated by a sense of "epistemic injustice" and the need to bring in the voices of scientists in the global periphery in order to solve social problems that are relevant to their constituent publics (Zhang and Burton 2022). Science policy should be careful of ostracizing potential allies amongst Chinese scientists, who could play a pivotal role in shaping policy in China as well as creating new biomedical innovations that could benefit not just Chinese populations but beyond.

With regards to industrial policy, as mentioned previously, precision medicine's rise in China is intimately tied to the favorable policy environment shaped by the Chinese state. Speaking of a precision medicine industry may be a bit premature, as many of the promises and claims of precision medicine have yet to be brought to the clinic—and have not yet been brought to market. The most concrete application of precision medicine thus far is the rapid rise of the genetic testing industry in China (Du and Wang 2020), but precision medicine's aspirations go beyond this niche industry. Nonetheless, it is conceivable that the groundwork for future biomedical innovations is being laid with the scientific research that is being conducted by scientists in China given the long time horizons of innovation (Mazzucato 2015).

We can learn three lessons for industrial policy from the example of precision medicine. *First*, as evidenced by the wide range of state agencies that have stepped up to provide funding for precision medicine research, there are multiple and overlapping sources of funding that precision medicine scientists and entrepreneurs can take advantage of, while providing some semblance of state guidance in the scientific field. These duplicate streams of funding provide enterprising scientists different opportunities to pursue funding should they fail to secure funding from major sources like NSFC, but it also has the potential for supporting weaker or suboptimal projects (but this is hard to predict with basic research).[17]

17 In interviews during my time of active fieldwork between 2016 and 2019, there was widespread recognition that the hype and enthusiasm for precision medicine observed at the time would fade, as the generous and multiple funding streams dry up. Respondents observed that much like other industries, there would be a consolidation in the industry, such as with the many biotech firms offering genetic testing services at the time.

Second, this is not to say that there is a presumed unity or coherence to the policy push to promote the precision medicine industry: While the policy idea and scientific project of precision medicine is somewhat in vogue in China, precision medicine is a case of "implementation before policy" (Greenhalgh 2008). Policymakers have yet to sort out how precision medicine will actually materialize and come to bear on existing market institutions and arrangements in healthcare, insurance, and the employment.[18] The governance of precision medicine and related biotechnologies have thus relied on certain forms of anticipatory governance, which has seemed reactive at times and created tensions, controversies, and unanticipated consequences (Guston 2014). There remain many obstacles that precision medicine entrepreneurs will have to sort out before any innovation can be scaled up and adopted widely within China and beyond.[19]

Third, the capacity and know-how in the emerging precision medicine industry has drawn on, particularly in genomics and the genetic testing industry, has relied on the open flow of ideas, knowledge, people, and technology. It is hard to conceive of further growth in this industry if these global flows are interrupted and further restricted. Again, much of the scientific talent in this industry grew out of the past few decades of scientific training, exchanges, and collaboration between Chinese and U.S. scientists and entrepreneurs. Some of these interactions have been facilitated by the state, such as with talent recruitment programs, but others have emerged more organically, outside of the purview of the state.

While the term precision medicine was removed from the 14th Five-Year Plan (2021–2025), precision medicine and its associated ideas, technologies, and tools are likely to continue to play a role in structuring scientific research and biomedical innovation in the coming years. The actors identified in this brief bibliometric analysis and the sources of funding identified will likely continue to play pivotal roles in the development of the precision medicine field and industry in China. However, as discussed previously, the further growth of precision medicine may be jeopardized by ongoing securitization of this research area, as well as increasing geopolitical tensions and mistrust between U.S. and Chinese scientists.

---

18 Another instance of this can be seen in the changing regulations with regards to access to medicines in China, which has vacillated between prioritizing availability and affordability (Li 2021).

19 As indicated previously, these challenges are manifold: for instance, (1) entrepreneurs hoping to take advantage of the data surplus in China need to work on linking the many data silos within hospitals, biobanks, gene banks, in private companies, in the public insurance system, and in emerging digital health technologies; (2) regulators and scientists also need to work out modes of data sharing, particularly with foreign and overseas entities, that protects privacy and data sovereignty but is not as restrictive as to choke off future innovation; (3) further harmonization of the regulation of innovative products in gene and cell therapy, which draw somewhat from precision medicine, so that trial data in China can be trusted by United States and other overseas regulators.

References

Aria, Massimo, and Corrado Cuccurullo. 2017. "Bibliometrix: An R-Tool for Comprehensive Science Mapping Analysis." *Journal of Informetrics* 11 (4): 959–75. https://doi.org/10.1016/j.joi.2017.08.007.

Au, Larry. 2020. "Imagining the Public: Anticipatory Discourses in China's Push for Precision Medicine." *BioSocieties*, August. https://doi.org/10.1057/s41292-020-00205-5.

———. 2021. "Recent Scientific/Intellectual Movements in Biomedicine." *Social Science & Medicine* 278 (June): 113950. https://doi.org/10.1016/j.socscimed.2021.113950.

Au, Larry, and Renan Gonçalves Leonel da Silva. 2021. "Globalizing the Scientific Bandwagon: Trajectories of Precision Medicine in China and Brazil." *Science, Technology, & Human Values* 46 (1): 192–225. https://doi.org/10.1177/0162243920930282.

Berman, Elizabeth Popp. 2011. *Creating the Market University: How Academic Science Became an Economic Engine*. Princeton, New Jersey: Princeton University Press.

Blasimme, Alessandro, and Effy Vayena. 2016. "'Tailored-to-You': Public Engagement and the Political Legitimation of Precision Medicine." *Perspectives in Biology and Medicine* 59 (2): 172–88. https://doi.org/10.1353/pbm.2017.0002.

Cao, Cong. 2017. "China's Approaches to Attract and Nurture Young Biomedical Researchers." National Academies.

———. 2018. *GMO China: How Global Debates Transformed China's Agricultural Biotechnology Policies*. New York: Columbia University Press.

———. 2021. "China's Evolving Biosafety/Biosecurity Legislations." *Journal of Law and the Biosciences* 8 (1). https://doi.org/10.1093/jlb/lsab020.

Cao, Cong, Richard P. Suttmeier, and Denis Fred Simon. 2006. "China's 15-Year Science and Technology Plan." *Physics Today* 59 (12): 38–43. https://doi.org/10.1063/1.2435680.

Cheung, Tai Ming. 2022. *Innovate to Dominate: The Rise of the Chinese Techno-Security State*. Ithaca, New York: Cornell University Press.

Coplin, Abigail. 2019. "Domesticating Biotechnological Innovation: Science, Market and the State in Post-Socialist China." Columbia University. https://doi.org/10.7916/d8-z1m3-ef53.

Du, Li, and Meng Wang. 2020. "Genetic Privacy and Data Protection: A Review of Chinese Direct-to-Consumer Genetic Test Services." *Frontiers in Genetics* 11. https://doi.org/10.3389/fgene.2020.00416.

Eyal, Gil, Maya Sabatello, Kathryn Tabb, Rachel Adams, Matthew Jones, Frank R. Lichtenberg, Alondra Nelson, et al. 2019. "The Physician–Patient Relationship in the Age of Precision Medicine." *Genetics in Medicine* 21 (4): 813. https://doi.org/10.1038/s41436-018-0286-z.

Greenhalgh, Susan. 2008. *Just One Child: Science and Policy in Deng's China*. First edition. Berkeley: University of California Press.

Greenhalgh, Susan, and Li Zhang. 2020. *Can Science and Technology Save China?* Ithaca, NY: Cornell University Press.

Guston, David H. 2014. "Understanding 'Anticipatory Governance.'" *Social Studies of Science* 44 (2): 218–42. https://doi.org/10.1177/0306312713508669.

Ibata-Arens, Kathryn C. 2019. *Beyond Technonationalism: Biomedical Innovation and Entrepreneurship in Asia*. Stanford, CA: Stanford University Press.

Lei, Ya-Wen. 2021. "Publics, Scientists and the State: Mapping the Global Human Genome Editing Controversy." *The China Quarterly* 246 (June): 400–427. https://doi.org/10.1017/S0305741021000229.

Li, Lantian. 2021. "Deconstructing and Historicizing Access to Medicines: The Changing Priority of Pharmaceutical Governance in China." *Frontiers in Sociology* 5 (January): 537919. https://doi.org/10.3389/fsoc.2020.537919.

Ma, Dali. 2019. "Boundary Repair: Science and Enterprise at the Chinese Academy of Sciences." *Social Studies of Science*, May, 0306312719846560. https://doi.org/10.1177/0306312719846560.

Mazzucato, Mariana. 2015. *The Entrepreneurial State: Debunking Public Vs. Private Sector Myths*. London: Anthem Press.

Murray, Fiona. 2010. "The Oncomouse That Roared: Hybrid Exchange Strategies as a Source of Distinction at the Boundary of Overlapping Institutions1." *American Journal of Sociology* 116 (2): 341–88.

National Research Council. 2011. *Toward Precision Medicine: Building a Knowledge Network for Biomedical Research and a New Taxonomy of Disease*. The National Academies Collection: Reports Funded by National Institutes of Health. Washington (DC): National Academies Press (US). http://www.ncbi.nlm.nih.gov/books/NBK91503/.

Olson, Maynard V. 2017. "A Behind-the-Scenes Story of Precision Medicine*." *Genomics, Proteomics & Bioinformatics* 15 (1): 3–10. https://doi.org/10.1016/j.gpb.2017.01.002.

Ong, Aihwa. 2016. *Fungible Life: Experiment in the Asian City of Life*. Durham, NC: Duke University Press.

Paul, Anju Mary. 2021. *Asian Scientists on the Move: Changing Science in a Changing Asia*. Cambridge: Cambridge University Press.

Prainsack, Barbara. 2020. "The Meaning and Enactment of Openness in Personalised and Precision Medicine." *Science and Public Policy* 47 (5): 647–54. https://doi.org/10.1093/scipol/scaa013.

Sleeboom-Faulkner, Margaret, Haidan Chen, and Achim Rosemann. 2018. "Regulatory Capacity Building and the Governance of Clinical Stem Cell Research in China." *Science and Public Policy* 45 (3): 416–27. https://doi.org/10.1093/scipol/scx077.

Stevens, Hallam. 2018. "Starting up Biology in China: Performances of Life at BGI." *Osiris* 33 (1): 85–106. https://doi.org/10.1086/699235.

Sung, Wen-Ching. 2010. "Chinese DNA: Genomics and Bionation." In *Asian Biotech: Ethics and Communities of Fate*, edited by Aihwa Ong and Nancy N. Chen, 1 edition, 263–92. Durham, NC: Duke University Press.

Wahlberg, Ayo, Christoph Rehmann-Sutter, Margaret Sleeboom-Faulkner, Guangxiu Lu, Ole Döring, Yali Cong, Alicja Laska-Formejster, et al. 2013. "From Global Bioethics to Ethical Governance of Biomedical Research Collaborations." *Social Science & Medicine* 98 (December): 293–300. https://doi.org/10.1016/j.socscimed.2013.03.041.

Xiwei, Zhong, and Yang Xiangdong. 2007. "Science and Technology Policy Reform and Its Impact on China's National Innovation System." *Technology in Society* 29 (3): 317–25. https://doi.org/10.1016/j.techsoc.2007.04.008.

Yu, Jun. 2017. “A Piece of History That Cannot Be Missed for Precision Medicine.” *Genomics, Proteomics & Bioinformatics* 15 (1): 1–2. https://doi.org/10.1016/j.gpb.2017.01.003.

Zhang, Joy Y., and Saheli Datta Burton. 2022. *The Elephant and the Dragon in Contemporary Life Sciences: A Call for Decolonising Global Governance*. Manchester: Manchester University Press.

Zhou, Yu, and Abigail E Coplin. 2022. “Innovation in a Science-Based Sector,” 39.

Zweig, David, Chen Changgui, and Stanley Rosen. 2004. “Globalization and Transnational Human Capital: Overseas and Returnee Scholars to China.” *The China Quarterly* 179 (September): 735–57. https://doi.org/10.1017/S0305741004000566.

Zweig, David, Chung Siu Fung, and Donglin Han. 2008. “Redefining the Brain Drain China’s ‘Diaspora Option.’” *Science Technology & Society* 13 (1): 1–33. https://doi.org/10.1177/097172180701300101.