Cooperation for Development

The Role of the State in University Science: Russia and China Compared

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Research is now organized on the basis of a global science system, articulated by English language journals, which partly subsumes national systems and is the source of most innovations. To be effective, national science institutions must be closely and continually engaged in, and contributing to, this global system. "Science and technology in one country" is no longer a strategic option. Russian science is characterized by very low rates of publication, citation and joint international authorship, relative to system and university size. The total number of papers produced each year is declining. Only Lomonsov Moscow State University is ranked in the first 750 universities in the world on the volume of published science in English. Between 1995 and 2012, the number of internationally coauthored papers increased by 168% worldwide but 35% in Russia. The closed door to international links is a legacy of the Soviet period. The situation in Russia contrasts with the spectacular growth of science in China and East Asia, powered by active and focused states with an internationalization drive. This article discusses the trajectory of East Asian science. While Russia cannot replicate the East Asian family or political culture, a vigorous internationalization policy would kick-start the transformation of national science.

Key words: research, universities, globalization, international comparisons, university rankings, policy, Russia, China

Introduction

The advent of the internet in the early 1990s brought with it major changes in science and university-based research [Peters, Marginson and Murphy, 2009]. The last two decades have seen considerable development of what can be called "global science," organized in the form of a single accessible research system articulated by worldwide English-language journals, collaborative networks and cross-border projects, the growing mobility of personnel, two large-scale data repositories focused on publication and citation metrics that are managed by Thomson-Reuters and Elsevier respectively, and the research ranking of institutions and national systems [Marginson, 2014]. National research systems continue – and across the world have become increasingly active sites – while at the same time they are partly subsumed into the global science system, to which they relate with greater or lesser effectiveness. Simultaneously, in policy circles there has been growing emphasis on investment in research and development (R&D) and in some countries "world-class universities" (WCUs), as well as programs designed to enhance industry innovation [Altbach and Salmi, 2011]. States pursue R&D and university research policy in the manner of the "global competition state" [Cerny, 1997]. They are constantly aware at both local/national and global/regional levels, focused on global comparisons, and consider strategy and programs with an eye on what their competitors are doing, much as they have long done in relation to military technology and energy sources [Bayly, 2004]. Strategically, they mostly parallel and imitate each other, like cautious conglomerates manoeuvring for an incremental advance in their market share. More rarely, they innovate, hoping to differentiate themselves to secure advantage. Whether it is grounded in reality or not, national capacity in science and technology are now seen as key causes of economic growth and prosperity – in fact, seen as basic to modernity itself.

This article compares and seeks to explain two differing responses to this common ecology: the trajectory of the state, its research institutes and universities in Russia and the trajectory of states and university systems in East Asia and Singapore (principally but not only in China) in the last two decades. In this article, "East Asia" refers to the North East Asian zone of Japan, Korea, China, Hong Kong SAR, Taiwan and Vietnam. It is coupled with Singapore in this analysis for historical-cultural reasons, as discussed below.

Russia and China entered the 1990s with a similar Soviet-shaped structure in science and higher education. After the 1949 revolution in China, Russian science and technology was far in advance of that of China. China was much poorer than Soviet Russia, and Soviet policy always saw capacity in science and technology as central to long-term survival. Until the Sino-Soviet split in 1960, Soviet aid and Soviet models played a strong role in China's development. China's higher education and research systems were closely influenced by Soviet forms. Under the Soviet model in China, science was concentrated in academies and specialized institutes associated with a range of ministries, while universities focused predominantly on teaching, except for a small number of comprehensive institutions [Smolentseva, 2015; Hayhoe, Li, Lin et al., 2011]. Path dependence was established, so that the legacy of Soviet influence persisted even after the Sino-Soviet split, up until China's reforms to education and science in the 1990s. To an extent, vestiges of the old Soviet model survive in China, in the form of instances of specialized universities under particular ministries, and in the major role played by the Chinese Academy of Sciences.

However, in the last two decades pathways have fundamentally diverged. First, while both countries have moved universities in the direction of comprehensive teaching/research institutions, and moved some specialized researchers from separate institutes into higher education, this process has gone much further in China than in Russia. Second, investment patterns have been fundamentally different. The end of the Soviet period in Russia triggered the complete or partial collapse of many research organizations and the exit of a large number of trained personnel. This was just before China decided in the mid 1990s to invest heavily in science and research, and build an R&D sector on the American scale – an ambition once harboured by Soviet Russia, but, it seems, less important to post-Soviet Russia, which has shifted its economic trajectory from a defence-driven military industrial state to a predominantly resource- and finance-driven state.

Arguably, the Soviet system is still running down and the next Russian science system is yet to emerge. In the last two decades, in contrast with almost every other research system in the industrialized world, published scientific outputs have declined in Russia, and there has been little progress in science infrastructure. In the same time period in East Asia and Singapore, there has been a rapid and massive growth in research infrastructure and scientific outputs, and in the extent of internationalization of science and universities. This happened in Japan earlier, between the 1960s and the 1980s. The dynamic growth of science spread to Korea, Taiwan and Singapore in the 1990s and to China in the last 15 years. The achievements of Chinese policy on science and universities are reviewed below. Japanese research is no longer improving, in terms of the quantity of science papers, the rate of citations and the ranking of universities, but in the other East Asian countries rapid improvement continues, in all three categories, with no end in sight to the upward progress.

The role and character of the state have been key to the dynamic developments in East Asia and Singapore. These systems share a common cultural foundation in Chinese civilization [Holcombe, 2011, p. 1–10]. They are conventionally labelled "Sinic." Regardless of whether they are single party states or electoral democracies, countries shaped by Chinese civilization share a common mode of state and pursue similar policies on science and universities in the present period. This state tradition is distinct from the differing English-speaking, Western European and Russian state traditions. These differences among regional political cultures inhibit the potential of science policy transfer from, say, China to Russia, but perhaps there are still lessons to learn from East Asia.

Global Developments

Science always has always been something of a global conversation but was primarily organized in national systems. The global science and technology system now overshadows all national systems, even the gigantic American system. While that country continues to play the leading world role, and sets many of the rules of global science – world journals are mostly U.S.-edited – there is a growing pluralization as many other countries strengthen their capacity. The proportion of all science that is produced in the United States is falling, an unstoppable tendency but one that generates concern in American circles [National Science Board (NSB), 2014]. However, science is a single largely open system. There are pockets of secrecy, especially in relation to technology, for strategic military and industrial reasons, but the vast bulk of strategic knowledge – knowledge that is powerful and useful for states and companies – is in the open space and flows freely around the world. It is a remarkable change in human affairs. It calls up the need for new strategies and behaviour.

Features of this world science system include the explosive growth of web-based global publishing in English, in the form of both major disciplinary journals and open source circulation of papers, ideas and data; the continuing growth in the number of countries that are active in science; the great increase in publications with international coauthors; the fact that two thirds of citations in the global English-language science literature are international (i.e., they are citations of work that originated in a country different from that of the authors doing the citing); and the central role now played by collaborative research grant programs such as the European Research Area. Between 1995 and 2012, the total number of published journal articles in Thomson-ISI Web of Knowledge increased by 47% but the number of articles with authors from at least two different countries increased by 168%. Between 1995 and 2012, the number of countries publishing at least 1,000 journal articles per annum, a proxy measure for the existence of a national research capacity, rose from 37 to 51 [Ibid.]. Table 1 sets out the countries publishing at least 1,000 papers in 2011. Countries that entered this group after 1995 include Croatia, Serbia, Slovenia, Chile, Malaysia, Thailand, Iran and Tunisia. The output of published science grew faster in Iran than any other country, increasing at 25.2% per annum between 1995 and 2011 [Ibid.]. The growing emphasis on research has become joined to widely distributed national policies designed to achieve WCU status for the nation's universities, or to elevate universities that are already at the level of WCUs. WCUs are conventionally understood as higher education institution (HEI) that are listed in the world top 100, 200 or 500 in the research rankings. In 2013, the president of Russia announced there should be five Russian universities in the global top 100 by 2020. Government funding was allocated to develop 15 selected universities toward this goal [Vorotnikov, 2013]. There are significant WCU programs in, among others, Germany, France, China, Japan, Korea and Vietnam [Salmi, 2009].

Table 1. Countries Publishing More than One Thousand Science Papers in 2011

Anglosphere	**European Union**	**Non-EU Europe**	**Asia**	**Latin America**	**Middle East:**	**Africa**
United: States: 212,394	Germany: 46,259	Russia: 14,151	China: 89,894	Brazil: 13,148	Iran: 8,176*	Saudi Arabia: 1,491*
United: Kingdom: 45,884	France: 31,686	Switzerland: 10,019	Japan: 47,106	Mexico: 4,173	Israel: 6,096	South Africa: 3,125
Canada: 29,114	Italy: 26,503	Turkey: 8,328	Korea: 25,593	Argentina: 3,863		Egypt: 2,515
Australia: 20,603	Spain: 22,910	Norway: 4,777	India: 22,481	Chile: 1,979*		Tunisia: 1,016*
New: Zealand: 3,472	Netherlands: 15,508	Ukraine: 1,727	Taiwan: 14,809	Latin America		
	Sweden: 9,473	Croatia: 1,289*	Singapore: 4,543	Brazil: 13,148		
	Poland: 7,564	Serbia: 1,269*	Thailand: 2,304*	Mexico: 4,173		
	Belgium: 7,484		Malaysia: 2,092*	Argentina: 3,863		
	Denmark: 6,071		Pakistan: 1,268*	Chile: 1,979*		
	Austria: 5,103					
	Finland: 4,878					
	Portugal: 4,621*					
	Greece: 4,534					
	Czech Republic: 4,127					
	Ireland: 3,186					
	Hungary: 2,289					
	Romania: 1,626*					
	Slovenia: 1,239*					
	Slovakia: 1,099					

* Countries that have entered the 1,000-paper group since 1997.

Source: Adapted from National Science Board [2014].

Science is no longer the province of the English-speaking world, Western Europe, Russia and Japan. It has become part of the business of middle-income and emerging states. It seems that countries need an indigenous science infrastructure just as they need clean water, stable governance and a globally viable financial sector. Most innovations in technology and product development, with the possible exception of those in the United States, are now sourced wholly or partly from outside the country, not national sources. (This follows directly from the pattern of publication of scientific knowledge – no country apart from the United States publishes more than a small proportion of the highly cited science papers, and little basic science is now produced that remains outside the world literature [see NSB, 2014].) Countries thus need to be effective participants in the one-world science system and fully in touch with current work; and to do this they must be themselves contributors and partners in the system. In turn, to be producers of research they must have an indigenous research capacity and train at least some of their research personnel. The alternative is a position of continuing scientific and technological dependence.

The point cannot be emphasized too strongly. The effectiveness of national and university science – whether old or new – now depends on its capacity to operate globally. National and university science everywhere is positioned on the edge of the global science system, and feeds off it. Everyone is borrowing freely from everyone else, in accessing the common store of knowledge. Countries partly disengaged from the global science system, such as North Korea, are increasingly penalized. It is inevitable that they will fall further behind. Because countries like North Korea do not work openly and collaborate freely, they do not full access to knowledge and cutting edge expertise from elsewhere. Because they do not contribute freely into the global system, their scientists lack profile and fail to build international relationships, based on continuous exchange and collaboration, which allow them to anticipate new knowledge as it emerges. Those countries do not draw strategic talent from other countries. Many of their best people want to leave to work at the cutting edge elsewhere. In this setting, open systems of science and people mobility prosper, like the American system. States with strong central authority in China, Korea and Singapore now realize this and have created broad highways between their science systems and the systems of other countries. Managed internationalization is a vital tool of strategy in East Asia [Wang, Wang and Liu, 2011; Postiglione, 2011; Yonezawa, Kitamura, Meerman et al., 2014].

The Importance of States

All over the world, the objective of state policy is to facilitate autonomous product innovations in capitalist industries. Nevertheless, in research and science, the state never finally vacates the field. Because research is largely a public good subject to market failure, it depends on prolonged state investment [Stiglitz, 1999]. (This also makes research infrastructure irreducibly expensive, which means that the poorest countries – those with per capita incomes of about $8,000 or less – cannot finance their own science systems, as is obvious from cross-country comparisons of research output [see NSB, 2014].) Therefore science policy and the organizational forms of research and research-based universities are closely implicated in the country's political culture, meaning that they are shaped by the tradition and evolution of the state.

In emerging systems, the capability and focus of the state are crucial to building infrastructure, funding research personnel, and organizing the government institutes and universities where research takes place. In general, where the state is fragmented, weak or corrupt or lacks coherent policies, the potential of universities is limited. Significant research programs cannot begin, especially if they require expensive equipment, materials and trained personnel. Once indigenous science is established, the imperatives change. It becomes increasingly important to nurture the independent capacity of research professors, institute directors and university executive leaders to make operational decisions. For example, governments are not in a strong position to decide on the direction of scientific creativity in the disciplines and are therefore unable to decide effectively on the desired national and international research partnerships. Only specialist researchers can make such decisions [Kerr, 2001]. The state also needs to encourage direct relations between, on the one hand, research organizations and, on the other hand, cities and localities, professions and employers, in order to enable research to have maximum take-up and use. However, the dependence of researchers on the state never evaporates. Government remains crucial to funding, especially in relation to basic science, but often even in the subsidization of commercially relevant research for industry [Organisation for Economic Co-operation and Development (OECD), 2013]. Also, governments often intervene in research content decisions, perhaps more than they should. Most governments influence the directions of research by establishing broad priorities among disciplines, and they often pick favourites in relation to research topics, even when for the most part the detailed grant allocations are handled by scientific peers [Santiago, Tremblay, Basri et al., 2008].

Political cultures and state traditions vary across the world. The core notions of state-science relations, namely autonomy and academic freedom, are practised in varying ways. All researchers want to operate free of interference, yet all are also nested in organizational and social contexts that sustain customary practices – whether through top-down regulation or voluntary initiative (and self-censorship) – and shape human agency itself. Scientific freedom and creativity are not wholly universal qualities. There are irreducible historical-cultural elements.[1] In East Asia and Singapore, and also in Russia in a different way, the state retains closer supervision (even of leading research universities) than occurs in India, in German, francophone and Nordic countries (notwithstanding the large Nordic states) and in the English-speaking world. These differences do not in themselves determine success or failure in science policy. Clearly, there is more than one way to sustain a high-performing research system. The U.S./UK model – the template of global rankings and World Bank development programs – the Nordic model, and the East Asian or "post-Confucian" model [Marginson, 2013]— are all associated with successful science systems, in specific circumstances [on the post-Confucian model see Marginson, 2013]. By the same token, it would be misleading to argue that the East Asian (Sinic) state is both necessary and sufficient to achieving advanced science universities, in Asia or anywhere else. Nevertheless, this kind of state is effective in the accelerated development of science, under the right economic and cultural conditions.

Sinic States and Sinic Learning

As noted, the East Asian countries and science systems lie within the historical boundaries of Sinic (Chinese) civilization. Arguably Vietnam, which was occupied by China for more than a thousand years, shares this geo-cultural region. The non-adjacent island state of Singapore in Southeast Asia has primarily Sinic political, economic and educational cultures. Although there are differences in language and political systems, and current tensions within the Sinic group, all sustain the comprehensive form of state that developed 2,200 years ago in Qin and Han China [Holcombe, 2011]. East Asian countries do not exhibit the tensions between state and society and between state and market typical of the English-speaking world, with its lim-

[1] The same insights about the irreducible importance of states and differences among state political cultures also underpin the comparative studies by Andy Green [2013], and Martin Carnoy and colleagues [2013] the latter in relation to the BRICS countries.

ited liberal states. Nor was East Asia closely affected by the egalitarian upheavals of the French revolution and 19th-century social democracy. Whether in single party or multi-party polities, national states in East Asia exhibit strong continuity in policy and personnel and a characteristically long-term view [Jacques, 2012]. Government posts enjoy high social status, attracting many of the best graduates. The Sinic state is not a welfare state – the Sinic family has a larger role than in Europe and North America – but it exercises overall responsibility for social order and prosperity. Although the Sinic state does not administer society in detail, it is supreme with regard to economies and cities, and intervenes at will [Gernet, 1996]. As noted, the present East Asian state intervenes in universities and science.

Sinic societies also share a common heritage of Confucian learning practices in the family. From infancy, self-cultivation through education is part of the mutual responsibilities of parent and child, even in poor families. It is believed that success in education derives primarily from effort, not talent. There is a broader and deeper commitment to learning than in other societies, and the role of education in determining social destinations is near-universal [Zhao and Biesta, 2011]. In East Asia secondary education is highly competitive, culminating in end-of-school examinations that determine who enters the high-prestige universities that are the fast track to stellar careers. Confucian self-formation in the home, a teaching profession in good standing, extra classes after school and private tutoring all contribute to exceptional levels of learning at school [Bray, 2007; Chua, 2011; Gernet, 1996]. East Asia and Singapore dominate the Programme for International Student Achievement (PISA), the triennial survey conducted by the Organisation for Economic Co-operation and Development (OECD) that compares student learning achievement at age 15. In the 2012 PISA results for mathematics, the leading seven systems were all post-Confucian. Those systems did almost as well in PISA science and reading. Even Vietnam, with a per capita income of half that of China and only 10% of the United States in 2013, does better than both the United States and Russia in all three PISA disciplines [OECD, 2014].

As Table 2 shows, not only are the average PISA mathematics scores very high, but the size of the highest achieving group is also large, and there are few students in the lowest achieving group. In Singapore, 40% of students are in levels 5–6 in PISA, compared to 8.8% in the United States. Only 8.3% of Singapore students are in the bottom group in PISA, compared to 24% in Russia [Ibid.]. Although post-Confucian societies are not egalitarian, student learning is distributed on an egalitarian basis without a trade-off between equity and excellence. It is a strong foundation on which to build a national science system. There is a large pool of potential candidates for research and other science-specific roles, and many people working in business, government and the professions tend to be comfortable with science and technology.

In addition to these elements from tradition, the Han comprehensive state and the Confucian education family, all Sinic countries have undergone an accelerated modernization stimulated by imperial intervention and later by global competition. Economic prosperity has been both cause and effect of this. The central state strategic focus on "catching up to the West," in education and elsewhere, is feasible because of sustained high economic growth. One feature of the Sinic state is its capacity to mobilize the population on the basis of deep common commitment. While East Asian states play an essential role in developing science education in the leading universities and the research system, they do so in tandem with strong drivers in the household [Freeman, Marginson and Tytler; Marginson, 2013]. Intense family investment in tuition beyond the formal classroom combines with society-wide pride in "rising China," "rising Korea," etc. The term "post-Confucian" captures the way that inner tradition is hybridized with modernization, which takes the form of external pressures that are absorbed into personal and national identity.

Table 2. East Asia, Singapore, Russia and Others in the Programme of International Student Assessment, Mathematics, 2012

School System	Position (n = 65)	Mean Score	% in Top Group (Levels 5–6)	% in Bottom Group (Below Level 2)
OECD average	–	494	12.6	23.1
Shanghai, China	1	613	55.4	3.8
Singapore	2	573	40.0	8.3
Hong Kong, China	3	561	33.7	8.5
Taiwan	4	560	37.2	12.8
Korea	5	554	30.9	9.1
Macao, China	6	538	24.3	10.8
Japan	7	536	23.7	11.1
Switzerland	9	531	21.4	12.4
Germany	16	514	17.5	17.7
Vietnam	17	511	13.3	14.2
United Kingdom	26	494	11.8	21.8
Russia	34	482	7.8	24.0
United States	36	481	8.8	25.8

Note: The Programme for International Student Assessment (PISA) conducted by the Organisation for Economic Co-operation and Development (OECD) measures the skills and knowledge of 15-year-old students.

Source: OECD [2014].

Research-Based Science in East Asia

In the last two decades, all countries in East Asia except Japan and Vietnam have increased their R&D at a rapid rate. In Hong Kong, the share of gross domestic product (GDP) allocated to research is modest. However, GDP per capita is high, so that even at a low proportion of GDP, the research universities are well funded by international standards. In 2011, Korea invested 4.03% of GDP in R&D, higher than any country in the world in 2012. China's R&D investment rose by more than 18% a year from 2000 to 2012. By 2012, it was 1.98% of GDP, well above the UK. Total R&D funding in China was $213.1 billion (constant 2005 U.S. dollars), which was already 54% of the level in the United States (see Figure 1). China's spending on R&D is on track to pass the US in the next decade. Research is closely tailored to centrally determined disciplinary priorities and joined to strategies for building capacity and continually improving outputs. Singapore and China, and, to a lesser extent other systems, pursue internationalization strategies designed to force early and rapid improvement, such as benchmarking with leading American universities and incentives in publish in English in leading journals. Taiwan, Korea and China pursue successful policies to persuade overseas trained nationals, who are at post-doctoral and mid-career stages, to return home. Singapore, Hong Kong and selected areas in China offer internationally competitive salaries.

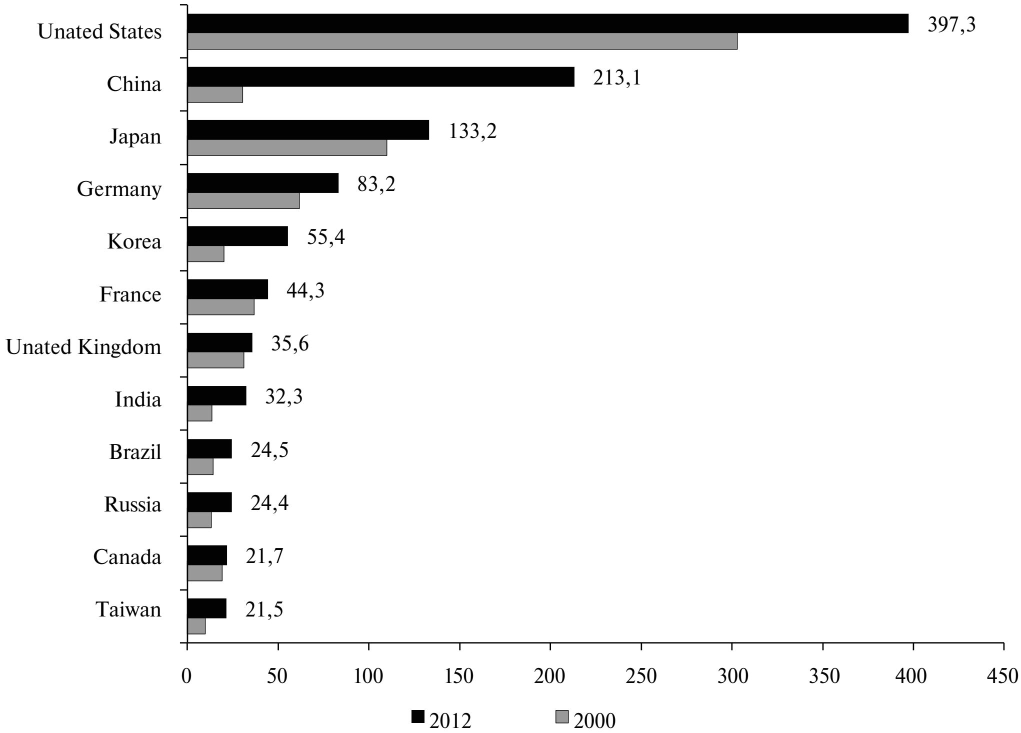

Fig. 1. Countries with Highest R&D Expenditure (constant 2005 USD, billions)

Notes:
Data for 2011, not 2012: Japan, Korea, India, Brazil, Turkey, Switzerland.
Data for 2010, not 2012: Australia, Taiwan.
Data for 2001, not 2000: Sweden, Denmark.

Source: UNESCO Institute for Statistics [2014], Central Intelligence Agency [2014], *Taiwan Today* [2014].

Published science is increasing almost as quickly as funding. Between 2001 and 2011, the number of journal articles authored or coauthored by Chinese scholars rose by 15.6% a year (see Figure 2, which compares the growth of science in China to the slower but significant increase in India, and decline in Russia). Over the same time period, published papers grew 8.8% a year in Korea, 6.4% in Singapore and 6.5% in Taiwan.

It is often argued that East Asian science has yet to prove itself because quality is lower than the United States and Western Europe, as measured by citation rates. Average citation rates are much lower than in the leading English-language countries, Germany and the smaller Northwest European systems: Switzerland, Sweden, Denmark, Finland and the Netherlands. But relative quality is changing. Average citations are high in Singapore – the National University of Singapore has a research profile similar to a strong UK university – and fairly strong in Hong Kong where, as in Singapore, most people use English as a primary language. Citations in China, Korea and Taiwan are improving rapidly. For example, in 2000 China published 3.7% of all papers in chemistry in the Thomson-Reuters Web of Science collection, based on all Thomson-accredited English-language journals. In 2012, that proportion had reached 16.9%, and China's total quantity of chemistry papers exceeded that of the United States.

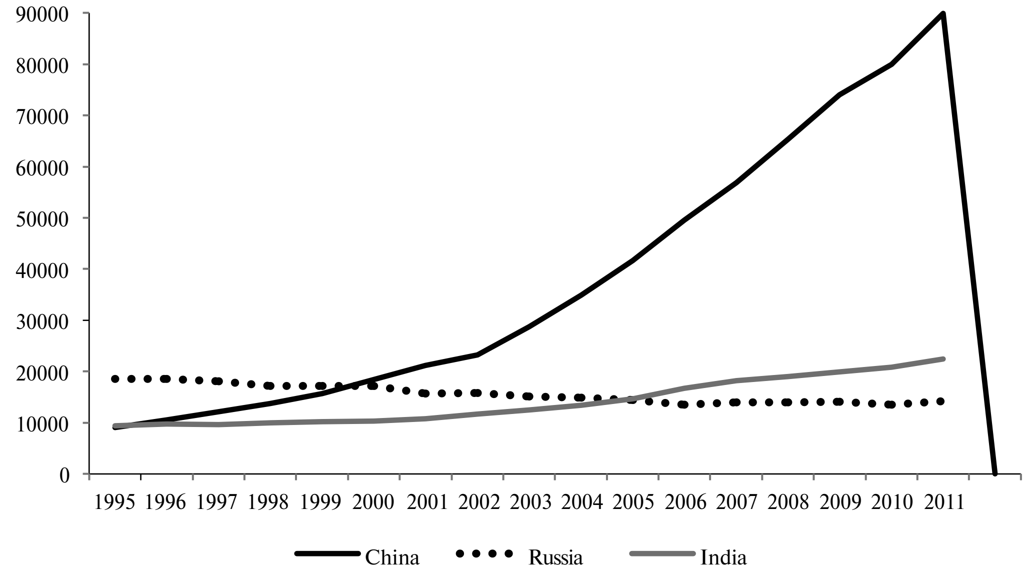

Fig. 2. Annual Output of Published Science Papers in Russia, China and India, 1995–2011

Source: National Science Board [2014].

More strikingly, in 2000 China authored just 0.6% of chemistry papers ranked in the global top 1% of citation rates in the Web of Science. Only 12 years later, in 2012, China published 16.3% of the leading 1% papers, half as many as the United States – an astonishing rate of improvement. There were similar patterns in engineering, physics and computing – where China publishes more top 1% papers than the United States – and mathematics [NSB, 2014]. China, Taiwan, Korea, Japan and, to some degree, Singapore have concentrated R&D in the physical sciences and related applied fields such as engineering, computing and materials. In Korea and Japan, this concentration supports advanced manufacturing. China also emphasizes research that supports accelerated modernization: energy, urbanization, construction, transport and communications. As this stage medicine and life sciences are much weaker.

All East Asian systems except Vietnam have been successful in creating world-class universities. (Arguably, at this stage Vietnam is too poor to do so, and it lacks a coherent state policy and uncorrupt ministry. See the analysis of higher education in Vietnam in Tran, Marginson, Do et al. [2014].) Between 2005 and 2013, the number of Chinese universities in the top 500 listed in the Academic Ranking of World Universities [(ARWU), 2014] rose from 8 to 28. Taiwan's top 500 universities grew from five to nine. ARWU understates the position of Asian universities, because 30% of the ranking position is determined by Nobel Prizes and there have been few Nobels in Asia. Leiden University's ranking provides several single indicators of research quantity and measures quality by citation rates, and is useful. One Leiden indicator lists universities by the number of science papers in the top 10% of the research field by citation rate [Leiden University, 2014]. There were 28 Asian universities in the world top 200 on the basis of 2009–12 research papers. Table 3 shows that the highest placed Asian HEIs are the University of Tokyo (1,389 top 10% papers, 29th in the world), National University of Singapore (30) and Tsinghua in China (49). These are not remarkable figures. However, current research rankings reflect R&D investments up to about 2005. When the last decade of investment is realized in the rankings, there will be many East Asian universities in the top 200, and pushing up in the top 50.

Table 3. Asian Universities in the Top 200 Based on Citation Rates, 2009–12

Rank	University	Country	# papers
29	Tokyo University	Japan	1,389
30	National University Singapore	Singapore	1,361
49	Tsinghua U CHINA	China	1,025
53	Zhejiang U CHINA	China	1,018
55	Nanyang UT SINGAPORE	Singapore	986
57	Kyoto University	Japan	982
67	Peking University	China	906
70	Seoul National University	Korea	901
72	Shanghai Jiao Tong University	China	887
87	Fudan University	China	784
95	Osaka University	Japan	724
100	National Taiwan University	Taiwan	695
103	University of Hong Kong	Hong Kong, China	669
117	University of Science and Technology of China	China	621
120	Tohoku University	Japan	606
123	Nanjing University	China	595
130	Sun Yat-sen University	China	563
135	Chinese University of Hong Kong	Hong Kong, China	548
145	Sichuan University	China	529
152	Harbin Institute of Technology	China	522
157	Yonsei University	Korea	517
169	Korea Advanced Institute of Science and Technology	Korea	493
180	Jilin University	China	466
182	Huazhong University of Science and Technology	China	463
183	Shandong University	China	457
185	Nankai University	China	456
199	Dalian University of Technology	China	428
200	Nagoya University	Japan	427

Source: Leiden University [2014].

What other factors have conditioned the phenomenally rapid growth of East Asian science, aside from the Confucian educational ethic in the home and high student learning achievement in the teenage years and high rates of economic growth? The short answer is effective Sinic states and effective programs for accelerated internationalization, carried out under the auspices of those states. In East Asia, government is politicized like it is everywhere, but on the whole it is more meritocratic and performance driven, and mostly less corrupt, than the state in the post-socialist countries [Marginson, 2010–13]. The East Asian states make science a high priority, focus substantial investment in it and set performance targets that are authentic and not just words on paper. They monitor the achievement of those targets; then they raise the targets further to drive progress. The result is real and rapid improvement [Marginson, 2011a]. Internationalization has been a key driver of improvements. Encouraged by the state, universities set incentives for English-language publication, bring back the diaspora from the overseas, attract foreign talent, support collaboration with foreign scholar-researchers and engage in systematic benchmarking with strong foreign universities [Wang, Wang and Liu, 2011]. A benchmarking approach to international comparison is a more focused, contextually appropriate, detailed and transformative strategy than a rankings approach [Altbach and Salmi, 2011]. East Asian governments see better rankings for their universities as the outcome of policy and of better performance, not as a principal policy instrument or driver [Liu and Cheng, 2005]. To focus on ranking outcomes as the objective of policy is to focus on reputation, and the appearance of global strength – rather than focusing on real education, real science and the substance of global strength.

Research-Based Science in Russia

Russia's current investment in R&D as a percentage of GDP is lower on the international scale than was Soviet R&D, and it is likely that it is lower in absolute terms (constant prices) than the peak R&D spending in the Soviet years. Figure 1 shows that Russia was tenth in total R&D in 2012. Although funding doubled between 2000 and 2012, it started at a low base. Russia's 2012 level of investment was only 6.% that of the United States, 11.4% that of China, and less than half the level of Korea, which has only one third of Russia's population [NSB, 2014].

Figure 3 provides data on the proportion of GDP allocated to R&D in 2012 or nearest year. It clusters national systems on a regional basis. Russia's total investment in R&D of 1.12% of GDP in 2012 was the lowest of the top 10 R&D countries except for India. Russia's investment in research was higher than South Africa but below Brazil and well below China. However, it is probably more appropriate to compare Russia not to the other members of the BRICS group of Brazil, Russia, India, China and South Africa, which are only now developing high-capacity systems, but to the English-speaking and Western European countries that, like Russia, have a longer history of developed research. In Figures 1 and 3 the standout countries are the United States, which is the dominant world power in R&D, as well as the smaller knowledge-intensive European countries in Scandinavia and Switzerland that have high rates of GDP investment and the rising science powers in East Asia and Singapore.

Russia's international position in globally published science is weaker than its comparative R&D investment. Russia was 10th in investment in 2012 but 15th in the number of science papers produced in 2011. Its output of published science in 2011 was 6.6% that of the United States, and 15.8% that of China. As indicated in Figure 2, the output of published science papers fell from 15,658 in 2001 to 14,151 in 2011, an average annual decline of 1%. Along with Japan (1.7% per year) and Sweden (0.6% per year), Russia was one of only three countries in the top 20 research producers where output declined. The average annual growth in output on a worldwide basis was 2.8% [NSB, 2014]. The decline of output in Russia can be attributed to the continued erosion and aging of the Soviet research system, the slow emergence of comprehensive research universities and the slow rate at which the whole system has internationalized. Published science in Russia is weaker than funded research in part because much of research in Russia takes place in the academies and other institutes outside the universities, and in specialist universities that service local manufacturing, energy, extraction and defence sectors [Scimago Lab, 2014]. Many of the papers produced by specialist institutes and universities are in Russian

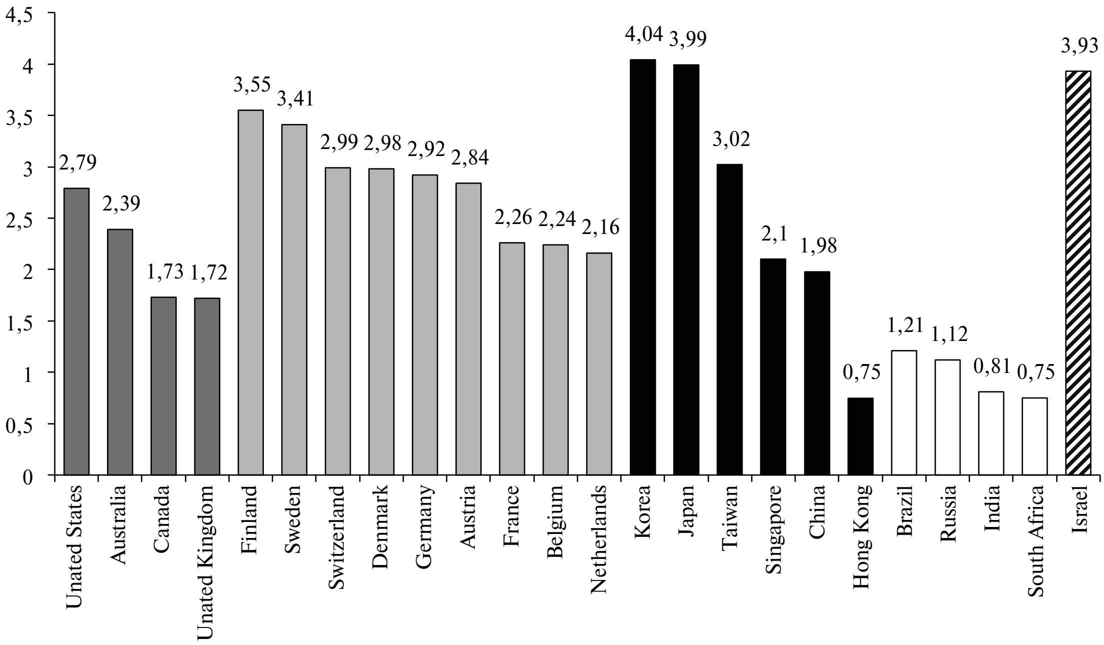

Fig. 3. Investment in R&D as a Proportion of GDP, 2012 (%)

Notes:
Data for 2011: Korea, Japan, Brazil, India, Switzerland.
Data for 2010: Australia, Hong Kong, South Africa, Taiwan.

Source: UNESCO Institute for Statistics [2014].

rather than English, do not show up in the global science data and do not lead to worldwide exchange of knowledge. There is nothing wrong with doing locally useful research, of course. Ideally, however, researchers are fluent and active in both the national and global languages, and both research conversations, rather than only one. The problem here is not just a lack of English-language versions of the research findings: the weakness in the global engagement of Russian science means localized work simply never gets close to the common global pool of knowledge, which, as noted, contains the overwhelming bulk of new scientific ideas. Between 1995 and 2012 the world's total number of journal articles with international coauthors rose by 168%, much faster than the number of journal articles as a whole. In China, Korea and Singapore, joint publishing multiplied by 8 to 12 times, depending on country. In Russia, the number of jointly published articles rose only 35% in that 17-year period [NSB, 2014]. There has there been little opening up since Soviet times. Furthermore, in its failure to grow collaborations sharply in the global era, the Russian science system has been radically out of step with most of the rest of the world, and radically out of step with all leading research countries outside Russia, whatever their political regime or foreign policy.

The Soviet strategy was "science and technology in one country." Contacts between Russian and foreign researchers were not encouraged [Smolentseva, 2015]. Useful research from abroad was translated into Russian and fed into the bounded national science system. Little research flowed out, to avoid giving away strategic secrets and to keep researchers in Russia [Marginson, 2010–13]. The closed-door legacy of this period continues to retard global awareness and engagement. The imperative of globalization is that the barriers come down and it becomes necessary to move freely among the local, national and global dimensions, while maintaining a clear national identity and strategy [Marginson, 2011b]. The Russian science system does not foster these attributes sufficiently, instead fostering too many people who find a way to turn their backs to the global realm, which suggests that old Soviet-era reflexes are still present. Russian science and technology are less internationalized than those of all the other countries ahead of Russia in the comparative tables. The focus on local research problems is often seen to be in opposition to, rather than in conjunction, with global research work [Marginson, 2010–13]. In short, there is a highly fragmented connection between the global science system and the national science system. Arguably, in many fields, a better term for the state of affairs is "disconnection."

Individual Research Organizations in Russia

Given these problems how well do individual Russian research universities, the academy of sciences and the non-university research institutes perform in comparative terms? One way to answer that question is by looking at science publication and citation data in detail. The most useful data sets are from Leiden University, based on Thomson-Reuters Web of Knowledge, and Scimago, based on the Scopus data set from Elsevier. The Leiden University ranking provides separate measures for each university of total science papers in global journals, citations per paper and the proportion of all published papers in the top 10% of their field of research, on the basis of citation rate. Leiden looks at just the top 750 universities in the world by paper volume. The only Russian university in the list is Lomonsov Moscow State University (LMSU), which occupies position 305 in the world in the league table based on paper volume – LMSU published 2,888 papers in the 2009–12 period analyzed by Leiden, compared to 29,693 at Harvard University, 9149 at Massachusetts Institute of Technology and 14,399 at the University of Tokyo, the top university from a non English-speaking country. Just 4.8% of LMSU's papers were in the top 10% of their field on the basis of citation rate. It was 697th out of the 750 universities on this citation rate, and published just 138 high-citation papers: 74 in natural sciences; 29 in life sciences; 15 in mathematics, computer science and engineering; 11 in earth and environmental sciences; six in medical sciences; and none in either cognitive sciences or behavioural sciences [Leiden University, 2014].

Table 4 compares LMSU's research output in the global science system with selected individual leading universities outside Russia in more detail. It compares LMSU's overall research output with a group of leading universities in the United States, United Kingdom, Germany, China, Brazil, India and South Africa: universities with a comparable role to LMSU. These individual universities are not necessarily the top one or two in their systems by paper volume or citation rate but have been chosen because they parallel LMSU as national universities, or capital city universities, or science and technology leaders. In the other BRICS countries there are more universities in the Leiden ranking than Russia's one. There are 16 in India, although with relatively low citation rates, 13 in Brazil, five in South Africa and no less than 83 in China, which has the world's second biggest research system.

Table 4 shows that at present, in terms of global science, LMSU is simply not in the same league as the top universities in the English-speaking world and Germany, and has been left well behind by the two Beijing universities in China and the large University of Sao Paulo in Brazil. Sao Paulo has a lower proportion of high-citation papers than LMSU (4.6% compared to 4.8%) but a better average citation rate. In aggregate terms it pumps out many more papers and many more high-citation papers. Like LMSU, Sao Paulo has the disadvantage of being a major national leader operating in a global research setting, but it is clear from these data that Sao Paulo's academic staff are more actively bilingual – they publish more than four times as many papers in English as staff from LMSU. Also, the University of Cape Town in South Africa is much stronger than LMSU in citation quality [Leiden University, 2014].

Table 4. Number of Science Papers and High-Citation Papers in Selected Universities, 2009–12

University and System	System	Number of Papers	Average Field Normalized Citation Rate (mean = 1.00)	High Citation Papers (Top 10% of Field)	High-Citation Papers % of All Papers %
University of California, Berkeley	United States	11,384	1.90	2560	22.5
Massachusetts Institute of Technology	United States	9149	2.05	2304	25.2
University of Cambridge	United Kingom	11,778	1.55	2163	18.4
University College London	United Kingdom	11,434	1.55	1833	16.0
Ludwig Maximilian University of Munich	Germany	7081	1.20	928	13.1
Technical University of Munich	Germany	5733	1.29	811	14.2
Tsinghua University	China	9713	1.03	1025	10.6
Peking University	China	9534	0.96	906	9.5
Indian Institute of Technology Kharagpur	India	4108	0.78	190	6.4
University of Delhi	India	3333	0.72	111	7.5
Lomonosov Moscow State University	Russia	2888	0.61	138	4.8
University of Sao Paulo	Brazil	12,319	0.67	634	4.6
University of Cape Town	South Africa	2333	1.06	257	11.0

Source: Leiden University [2014].

Leiden also provides breakdowns of the above data on the basis of broad discipline groups, enabling universities' strong research areas to be identified. At LMSU there is no strong area. The high-citation proportion is greater in earth and environmental sciences (7.9%, with an average citation rate of 0.77) than other areas. There are no high-citation papers in the English-language literature in cognitive and social sciences. Despite Russia's historical strengths in mathematics and engineering, there were only 15 high-citation papers in those disciplines over the four years, and 4.7% of all papers received high citations. The average citation rate was 0.63 [Leiden University, 2014].

These data underline the distance that even the country's top research university must travel in order to match the research capacity and performance of the leading universities Europe, the English-speaking systems and East Asia. This should not be surprising. It has taken 15 years for China to build a strong research system on the basis of exceptional and continually increasing levels of investment, and China does not yet have top 100 universities except on the basis of volume of papers. It has taken 25 years of exceptional investment and focused policy for the National University of Singapore – which, at this stage, is significantly stronger in research than any mainland Chinese university – to achieve the standard of a leading Northwestern European university in citation rates and high-citation papers.

The Scopus data collection Scimago, unlike the Leiden ranking, allows the output of non-university research organizations to be explored. There are also more papers in the Scimago collection than in the Leiden collection because there is greater inclusion of formats other than research articles. In addition, Scimago includes 2,744 university and non-university research organizations ranked in order of volume of papers, many more than the 500 in ARWU and the 750 in Leiden. This allows other Russian universities, and research institutes, to be investigated. Table 5 shows that when using the larger list in Scimago, China again strongly outperforms both the Russian academy and the Russian universities. For a non–English-speaking country, the Chinese Academy of Science, which in volume terms is the second largest research organization in the world, has a good academic impact factor (normalized across academic fields) of 1.01. Tsinghua University is at 0.96. The Russian Academy of Sciences is the third largest research organization in the world but its impact average for papers published in English is only 0.54 and below LMSU, which is a low 0.63 [Scimago Lab, 2014].

Table 5. Output of Science Papers from National Academy and Leading Universities in China and Russia, 2007–11

World Rank in Volume	Research Organization	System	Total Volume	Normalized Impact[a]
2	Chinese Academy of Sciences	China	157,814	1.01
11	Tsinghua University	China	48,396	0.96
19	Zhejiang University	China	42,606	0.87
24	Shanghia Jiao Tong University	China	39,399	0.81
3	Russian Academy of Sciences	Russia	97,105	0.54
115	Lomonosov Moscow State University	Russia	20,151	0.63
624	Russian Academy of Medical Sciences	Russia	5,694	0.63
660	St. Petersburg State University	Russia	5,404	0.61

Note: [a] The average is 1.00; the average for Harvard University is 2.40.

Source: Scimago Lab [2014].

Scimago also measures academic research impact, with its field-normalized impact indicator (NI). This provides a useful comparative measure of citation-related quality of papers on an averaging basis across research organizations. In the Scimago collection, the current top eight research universities in terms of paper volume are LMSU, St. Petersburg State University, Novosibirsk State University, Ural Federal University, Southern Federal University, Kazan Federal University, Moscow Engineering Physics Institute, and Moscow Institute of Physics and Technology. Those below LMSU and St. Petersburg State are currently ranked between 1,207 and 1,698, which in volume terms is not at all close to the world top 100. The policy goal of the five universities in the top 100 is a long way from present practice. Because the highest-quality Russian research institutions are small, the list of high-impact Russian research organizations is different from the list of highest volume research institutions, except that the Moscow Engineering Physics Institute appears on both the Scimago lists. None of the high-impact organizations is a comprehensive university. They are all working in physics and its applications, including nuclear, energy, space and engineering. The Institute for High Energy Physics is in the world's top 80 organizations in relation to academic impact as measured by the NI indicator [Scimago Lab, 2014]. Six of the leading 12 Russian organizations on impact are members of the Academy of Sciences, indicating that, notwithstanding its poor overall impact ratio, it retains pockets of research excellence.

Conclusion

In summary, the system attributes that are associated with the spectacular success of China and other East Asian countries, in building science capacity and outputs, are absent or largely absent in Russia. First, like most countries, Russia lacks the Confucian learning tradition at home, and in-school learning achievement is average in terms of international comparisons. Traditionally, Russians see their country as strong in mathematics and physics. This does not show in the PISA results. However, it is apparent in pockets of research excellence, as the Scimago data reveal. The continuing quality of physics-related research can be understood as part of the legacy of state-managed Soviet science.

Second, Russia has not benefitted from economic growth on the same scale as China, which in China has augmented household incomes, which in turn are fed into part of the cost of tuition. As a result, the state in China has had more resources to fund infrastructure, research, WCUs and scholarships for high-achieving students. Nonetheless, Russia arguably could have expended more on R&D funding than it has, especially over the last 15 years, which have seen moderate economic growth overall.

Third, and most important, Russia lacks an East Asian–style state. The characteristic East Asian state takes a comprehensive responsibility for social order and prosperity. The quality of the bureaucracy is high and the merit principle is generally accepted. There is corruption, but arguably on a lower scale than in the Soviet and post-Soviet states. In science in China, there are two problems that are larger than corruption: arbitrary government interference in decisions that should be made by scientists and based on the logic of development of knowledge, rather than political factors; and cases of repression of and pressure on critical public intellectuals. Repression and pressure used to be a problem in one-party Singapore also, and arguably the potential is still there. Over-centralization and top-downism are potential dangers in Sinic states, but it is possible to avoid the worst excesses, and to encourage a controlled devolution of authority. The upside of all that centralized attention is the long-term approach taken by the Sinic state and its critical and realistic approach to national improvement. It creates an authentic policy setting – targets and performance measures are real, and compliance must be substantial rather than ritualistic (or faked). In this era, Sinic states focus on catching up to the West. Theybenchmark everything instinctively in terms of leading countries. Thus these states readily foster the internationalization strategies in science that are so crucial to accelerated progress in China, Singapore, Korea and Taiwan.

Finally, as discussed, Russian science has low levels of international engagement by comparison with parallel national science systems across the world – in the English-speaking world, both of Western and Eastern Europe, East and Southeast Asia, Brazil and India. Russia is partly decoupled from and ineffective within the global research system. English-language skills are not developing rapidly as they are in East Asia, and the comparative publication, citation and research collaboration data indicate a serious problem.

Russia cannot replicate the spirit of the Sinic family. It cannot become a Sinic state. However, it can return to being a nation-building state of the Russian kind in terms of universities and research, and it can internationalize its research system, if it chooses to do so. Countries with a broad range of political cultures and institutional configurations have internationalized universities and science. Russian universities, research institutes and the academies of sciences are unlikely to take internationalization far without strong policy buy-in by the state. The ultimate key to a renovated research system in Russia is reform of government. In science policy, the post-Soviet state inherited from the breakup of the Soviet Union has been lethargic, parsimonious and, at worst, indifferent to the running down of research. Until the culture of government changes, Russia will not be able to return to the front table in science.

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