CHAPTER 2

Global Cooperation and National Competition in the World-Class University Sector

Simon Marginson

Abstract

Institutions of higher education generate many individual and collective benefits, on both the local/national and the global planes. World-class universities operate as a single network, one that is increasingly integrated and also operates as a positive sum, with the leading research nations fostering emerging science countries through collaboration. While world-class universities mostly function as exclusive social institutions in local/national contexts, subject to middle class capture and often implicated in growing income inequalities, on the global scale they have more freedom to pursue solidaristic and collective approaches. 'Flat' cooperative science works differently to markets or corporate command structures. The most important global common goods associated with world-class universities are research itself and the systems of communications and people mobility associated with networked activity. The last two decades have seen explosive growth in both total science outputs and joint international papers, an increasing proportion of output. Many more nations are entering the open global system. World science power is more plural, with remarkable growth and improvement in China, South Korea and Singapore (though the main achievements are confined to physical sciences of STEM) and developments in parts of Europe and Latin America. While nation-states mostly invest in research to secure national competitive advantage, global relations in higher education and research are primarily cooperative and the global science system evolves according to its own logic. However, global/national tensions can destabilize cross-border activities, though less in science than in global people mobility and communications. It is becoming more essential for world-class universities to strengthen their local relations and contributions, as well as advance global agendas.

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Keywords

Globalization – higher education – research – science – international collaboration – networks – China – Singapore

1 Introduction

Since the early 1990s and the advent of the internet and communicative globalization, the size, scope and contributions of higher education and science have been transformed. The larger socially engaged kind of higher education that emerged in the United States (US) in the 1950s–1970s – a national system with more institutions, larger institutions and growing institutions, and a distributed (albeit uneven) research capacity, a system that creates a very broad range of individualized and collective goods and readily connects across borders – has spread on the planetary scale. The first mover US American templates for higher education and science have been influential, even hegemonic in domains such as language of use and the organizational forms of the research university, but have not been wholly determining. Standard global templates are hybridized with local structures and agents. The logic of global higher education and science is more that of an open collaborative network (Castells, 2000) than a vertical command system, a closed oligopoly of market share, or an arms race in technological advantage (though from time to time, universities and science are annexed in unstable fashion to national or commercial projects in each of these categories).

This collaborative global network is continually fed by cross-border research exchange and people mobility, the global common goods integral to research-based higher education. A principal aspect has been the emergence of a more pluralized set of science nations and research-intensive or 'World-Class' universities (WCUs),[1] facilitated not only by the network growth typical of knowledge-based flows but by the global dispersal of national economic capacity.

1.1 *Participation*

From 1995 to 2015 the world Gross Tertiary Enrolment Ratio (GTER) as measured by the United Nations Educational Social and Cultural Organization's (UNESCO's) Institute of Statistics, rose from 15.6 to 35.7 per cent, with four fifths of the 215.9 million tertiary students enrolled in full degree programmes.[2] In more than 60 education systems the GTER now exceeds 50 per cent (UNESCO, 2018a). The quality of mass higher education, and rates of completion, vary by country. In the poorest 30 per cent of systems participation mostly remains very low (Marginson, 2016a). Nevertheless, by any measure the world is undergoing a great growth of educated 'capability', to use Amartya Sen's term (Sen, 2000).

The growth of higher education and of science are driven by the globally pervasive dynamics of modernization and development. The process is social and cultural as well as political and economic, and larger than the drive for capital accumulation, which is the most obvious motor. It is also highly uneven, within and between nations. Rajani Naidoo (2014) refers to 'combined and uneven development'. Conditions for building higher education vary, in terms of economic resources, the coherence of policy and state agencies, inherited learning cultures and the size of the middle class. Regardless, in emerging nations the ten thousand-year-old Neolithic world, the world of semi-subsistence agriculture edged by villages and small towns, is being swallowed up by the spread of cities and the manufacturing and service economy. Meanwhile, in countries like the United States, industrialized at an earlier time, regional towns and cities are partly displaced by globally connected metropolises absorbing a growing share of capital and people. Universal communications quicken development. Between 1995 and 2017, the estimated number of worldwide internet users grew from 16 million to 4,157 million, moving from 0.4 per cent of the global population to 54.4 per cent (Internet World Stats, 2018).

Above all, urbanization, growth in the proportion of the population that lives in cities, especially growth in the urban middle classes, sustains the growth of tertiary enrolments. Between 1970 and 2016 the urban share of world population rose from 36.5 to 54.3 per cent (World Bank, 2018) (Figure 2.1). As families move to the cities and into the wage and mass market economy their measured income expands and aspirations for advanced education grow and become realizable. Cities incubate family demand for upper secondary and tertiary education, concentrate political pressure on governments to expand provision, and enable economies of scale: comprehensive colleges and universities are really sustainable only in cities or in sites nearby to them. Growth of educational infrastructure further funnels and magnifies aspirations for education, triggering the supply of more places and more institutions in a continuing process. Higher education comes within sight of the whole urban population, not just the middle class, pushing social demand/supply of colleges and universities to 50 per cent and beyond in all high-income and middle-income countries.

Global demand for higher education will expand much further. For Brookings, Homi Kharas (2017) states that the global middle class reached 3.2 billion persons in 2016, half a billion more than previously projected. (The middle

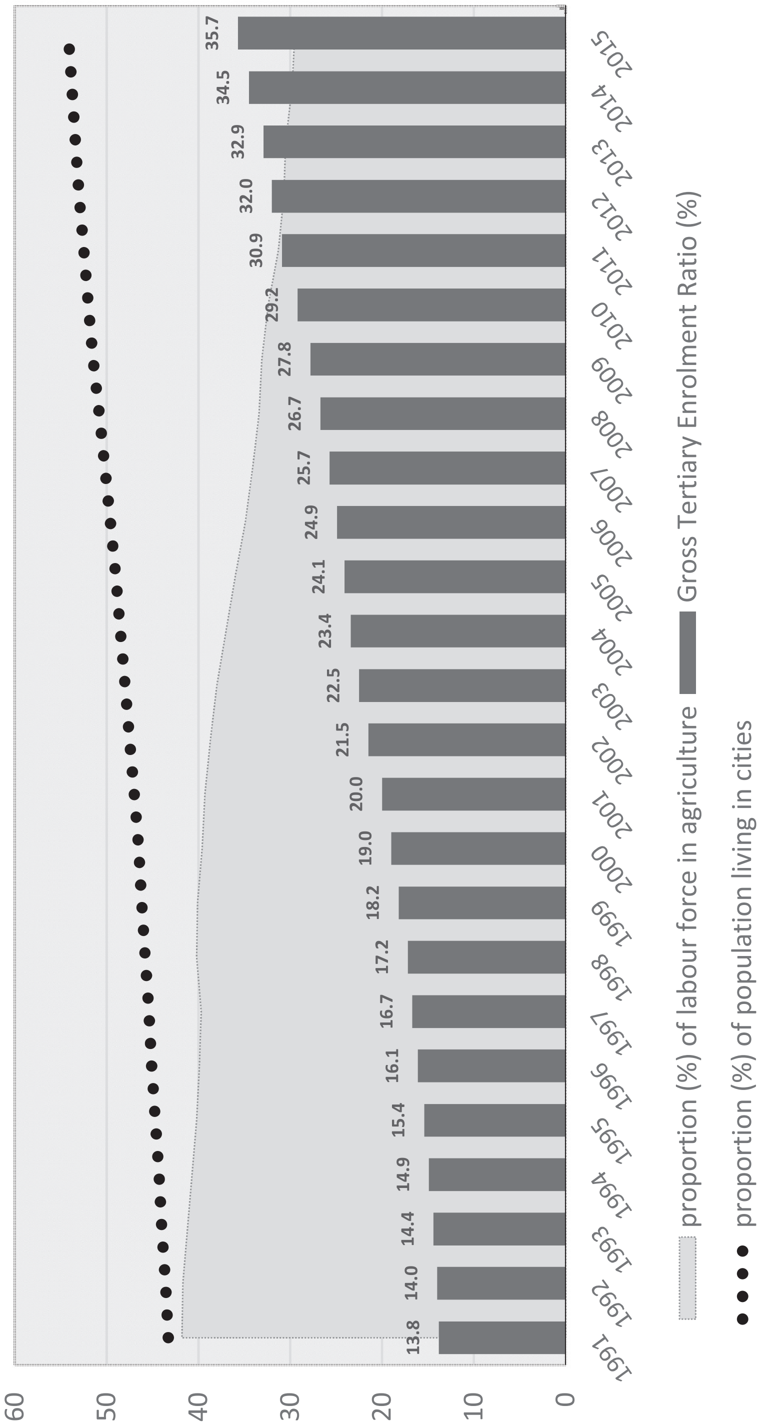

FIGURE 2.1 Worldwide gross tertiary enrolment ratio (%), compared to proportion of people living in cities (%) and proportion of labour in agriculture (%), 1991–2015

class is defined as persons with incomes of US$10–100 a day in 2005 purchasing power parity values). Kharas finds that 'within two or three years' the majority of the world's inhabitants will be middle class (Kharas, 2017, p. 2). The growth of the middle class is principally sustained by three of the world's four most populated nations: Mainland China (hereafter China), India and Indonesia (the other is the US). In China, participation in tertiary education reached 43.4 per cent in 2015, in India 26.9 per cent, and in Indonesia it was 31.1 per cent in 2014 (World Bank, 2018).

Gert Biesta (2009) defines the three purposes of higher education as 'qualification, socialization and subjectification'. 'Qualification' includes not just the formal certification of graduates but their acquisition of knowledge and skills for work and living. 'Socialization' refers to the preparation of citizens in the sensibilities and attributes necessary to functioning members of a larger collectivity. 'Subjectification' refers to the formation of distinctive self-determining or self-forming persons making their own pathway through the world (Biesta, 2009, pp. 39–41; Marginson, 2018a). The explosive growth of higher education brings with it growth in the number of qualified persons, in persons socialised as citizens, and in persons with agency freedom. Whether there will be a concurrent expansion in social opportunities to utilize these freedoms, severally and together, is less apparent (Cantwell, Marginson, & Smolentseva, 2018, Chapter 16). All the same, higher education's potential contribution to the common good is being enlarged worldwide at a rapid rate.

1.2 *Research*

At the same time, in high participation countries and in some other systems, there is equally rapid growth in the stock of knowledge in the form of published science. The 1990s internet sealed the establishment of a dominant world system of English-language journals. This coincided with growth in knowledge-intensive industrial production, which was also catalysed by information and communications technologies. Together these developments set in motion today's accelerated growth and spread of scientific capacity and outputs.

The role now played by global science makes it more necessary to develop national scientific capacity. To access global science, nations need their own trained people, not just as users but as producers of research who interact effectively with researchers abroad. In a growing number of countries research science has moved from the margins of policy to the normal business of state. Most high-income and many middle-income countries now want their own science system, alongside clean water, viable banking and stable governance. Increasingly also, the WCU is seen as the optimal institution for housing

TABLE 2.1 Gross expenditures on R&D (constant 2005 US dollars, PPP), eight leading science countries: Five-year intervals (1990–2015)

	1990 $s billion	1995 $s billion	2000 $s billion	2005 $s billion	2010 $s billion	2015 $s billion	R&D as proportion of GDP 2015 %
United States	152.4	184.1	268.6	326.2	408.5	496.6	2.74
China	n.a.	12.8	33.0	86.8	213.5	408.8	2.07
Japan	64.9	76.6	98.8	128.7	140.6	170.0	3.29
Germany	36.0	41.0	53.6	63.9	87.1	114.8	2.93
South Korea	n.a.	13.2	18.5	30.6	52.2	74.1	4.23
France	23.4	27.7	33.2	39.5	51.0	60.8	2.22
India	n.a.	n.a.	15.7	26.5	43.7	50.3	0.63
United Kingdom	18.7	19.6	25.1	30.6	37.6	46.3	1.70

n.a. indicates data not available. PPP = Purchasing Power Parity data to enable cross-country comparability.
SOURCE: DATA FROM NSB (2018, TABLE A4-12)

researchers and facilitating the cross-border circulation of knowledge and people normal to global science.

Together this package of tendencies, assumptions and goals has been transformative. There has been rapid growth in the nations actively investing in research and development (R&D), the proportion of Gross Domestic Product (GDP) devoted to R&D in emerging science systems, in total R&D investment, and in total scientific output. Table 2.1 demonstrates the spectacular change in China and South Korea. Between 1991 and 2015 the share of GDP allocated to research increased from 0.72 to 2.07 per cent in China, and from 1.83 to 4.23 per cent in South Korea, the highest level of any country in the world. The mature research system in Japan also increased its GDP commitment to R&D over that period, from 2.68 to 3.29 per cent. East Asia now spends much more in total on research than does either Europe/UK or North America (NSB, 2018, table A4-12). The data are for all investment in R&D, including industry spending. Direct investment in universities varies between 5 and 30 per cent of R&D, depending on country, but the universities' role is larger than this suggests: in most countries part of industry R&D is conducted in universities, and universities train most researchers with PhDs, wherever they work.

Between 1990 and 2015 all the science nations in Table 2.1 more than doubled their research spending in constant dollars. The United States research system tripled its spending over 25 year period. China grew its R&D outlay from only US$12.8 billion in 1995 to US$408.8 billion (32 times larger) 20 years later, moving close to the US total (NSB, 2018). At the same time, research in Northeast Asia and Singapore, the Chinese civilizational zone, also made major advances in quality, as is discussed below.

In sum, the total world output of science papers, most of them by university researchers and many of them fed into knowledge-intensive industries, rose from 1.19 million in 2003, to 2.30 million in 2016, representing growth of 92.5 per cent (NSB, 2018). The 2003–2016 period also saw worldwide tertiary enrolments increase by 72.1 per cent (UNESCO, 2018a). Each of mass teaching/learning in higher education, science, and research universities, are growing at unprecedented rates and becoming more central to society.

This multiplication of students and research, both at the same time, drives growth in the status, number and size of globally networked WCUs. Multi-disciplinary research universities have expanded their roles, size and status within nations, at the same time as they are building activity as global players. The contribution of WCUs to the common good is not fixed but open in historical terms. On one hand, *the common good is inherent in the globalized higher education and knowledge system*. This is a function of open, expanding global networks, to the extent that their core substance is knowledge and information, which are global public goods in economic terms, rather than capital. Networked WCUs are disposed to secure mutual positive sum benefits and in a common manner. On the other hand, the contributions of WCUs to the common good are the subject of contestation (and varying interpretations) and are articulated by nation-state policies and by the missions and strategies of WCUs themselves. Within the common good there are many interests in play.

1.3 *Contents of the Chapter*

This chapter focuses on the WCU sector, especially its globally networked research activities. Though WCUs house only a small proportion of students – the top 1000 research universities enrol about 7–8 per cent of the world tertiary population – they generate many collective and individual benefits, in both the national and global dimensions. The question addressed here is: ‘What are the contributions of World-Class Universities to the common good, especially the global common good?’ The joined-up potential of WCUs is much larger than is suggested by the neoliberal model of university as self-serving firm with customers/students and a ‘brand value’ (proxy for equity price) that is determined by ranking position. Consider the robust capacity and drive of WCUs to sustain international relations in a world of nation-states. This drive cannot be explained in terms of individualized profit motives: most cross-border activity has to be subsidized. While there is competition within the networked global system, on the whole systemic relations and benefits are aggregative, not zero-sum. The emergence of a larger group of high science countries matters not only because it signifies a multi-polar world in power terms, though that is important, but also because it expands the scope of the shared network in which all nodes are enhanced. The chapter focuses not just on individual WCUs and their global distribution but also on the combined effects of science/WCUs as a collectively networked whole.

Section 2 of this chapter reviews the definitions of public goods and common goods, and the various global common goods produced by WCUs, in the context of the larger set of individualized and collective contributions that they make. Section 3 expands on the workings of the worldwide research system, which arguably is the most important part of that WCU contribution to global common goods, mapping patterns of scientific production and cooperation. Section 4 is a brief conclusion.

2 Public and Common Good(s) in WCUs

2.1 *Public Good(s) in Higher Education*

Public Good (Singular). The term 'public good' normally refers to the broadly distributed general welfare or condition of virtue of the public, meaning society as a whole. 'Public good' can be highly normative. It is sometimes equated with the European feudal metaphor of the 'commons', a shared resource that all can utilize, not subject to scarcity or contaminated by congestion, such as a river or a pasture where all can graze their animals (Mansbridge, 1998). Here it moves toward 'common good' (see below). It is also associated with notions of democratic forms, openness, transparency and popular sovereignty.

Public Goods (Plural). This term is used more precisely than the singular public good, but has two different meanings (political, and economic) that only partly overlap.

In the political definition, public goods are outcomes produced in the state sector or otherwise controlled by government/state. Matters become public because they are of broad concern or effect and so must be resolved by the state (Dewey, 1926).

In the economic definition, public goods cannot be produced profitably in a market because they are non-rivalrous and/or non-excludable (Samuelson, 1954). Goods are non-excludable when the benefits cannot be confined to single buyers, such as clean air regulation. Goods are non-rivalrous when consumed by any number of people without being depleted, such as a mathematical theorem, which sustains its value as knowledge indefinitely and on a global basis. Private goods are neither non-rivalrous nor non-excludable and may be produced and sold in markets. Economic public goods and part-public goods require at least some state funding or philanthropic support. For example, knowledge is a natural economic public good (Stiglitz, 1999). It can be artificially privatized at the point of creation (e.g. by patent or copyright), and control of the artefacts in which it is embodied may be enforced by law, but once knowledge is revealed, its non-rivalrous and non-excludable qualities become dominant. The knowledge itself is readily duplicated without cost and its artefacts are freely reverse engineered and pirate-copied.

The economic definition of public goods is influential in policy because the problem of market failure appears to provide a rationale for the public/private division of costs. Using this formula, the state funds up to the point where market failure ends, after that the individual pays. The state pays only for people who cannot pay for themselves. But this formula carries two problems. One is the assumption that the distinction between public and private goods is always based on natural qualities. While some economic public goods, like knowledge or street lighting, are intrinsically public as Samuelson imagined, this does not exhaust the potential for public goods. There are other public goods that are determined by social relations and state policy. Education and health become turned into economic public goods when they are produced on a universal basis without distinctions of value, so becoming non-rivalrous and non-excludable.

The second problem in Samuelson's formula is that of zero-sum, the idea that if a good is more public it is less private, and vice versa. This drives the policy assumption that the private share of costs should be proportional to the private share of benefits. But this makes no sense in relation to policy-created public goods – for example, when society deliberately chooses not to provide education on a market basis, because this has perverse outcomes (e.g. restricted access and distributional inequalities) and there are additional public benefits to be gained from a shared, cooperative, universal approach, which requires non-market financing.

Rather than the intrinsic character of higher education (public or private) determining its source of finance, financing is one of the factors that determines the public or private (i.e. non-market or market) character of the activity. Teaching and student places can be organized either as economic public or private goods. Systems with full cost private tuition fees at the point of access tend to be more hierarchical in value, in the manner of all market-produced goods, dividing between high value and low value student places. High value places, attached to prestigious institutions and high-income degrees, are scarce, subject to fierce social competition, and targeted by affluent families for private investment. The families that access those places, and the educational institutions that house them, focus on higher education as private individual goods rather than collective (common or joint) public goods. However, in most countries, government funding extends more broadly than just the market failure problem. Most national populations expect governments to treat student places as non-market goods, for political reasons, to expand citizen rights and secure a measure of social equity.

When policy moves away from the minimalist naturalistic approach to public goods and the zero-sum idea of public/private goods, the rationale for a zero-sum public/private split of financing collapses. It should be emphasized that in higher education and research, public and private goods are not alternatives but additive. An expansion of each kind of good can augment the other. When graduates gain enhanced 'qualification' in Biesta's (2009) sense they also gain 'socialization', a capability in more developed and productive social, political and economic relationships. This is a collective, mutual and public benefit. When there is more qualification there is also more socialization. It is not zero-sum. The public financing of research in universities that connect to industry and government directly and indirectly generates many other public and private goods, with no zero-sum choices in sight.

In sum, there are two contrary ideas of the public/private boundary, based respectively on the state/non-state divide and the non-market/market divide. Rather than choosing one against the other, or compressing them into a single market/state dichotomy (highly misleading), it is better to retain the two different clear-cut definitions of public/private goods. Both tell us something useful. Arguably, by using both definitions together within one framework higher education is more effectively explained. This idea has been developed elsewhere (Marginson, 2018b).

2.2 *Common Good(s) in Higher Education*

Common Good (Singular). The singular 'common good' is mostly understood as a shared condition of well-being and freedom, or virtue, at the level of society as a whole.

Common Goods (Plural). The term 'public goods' does not necessarily mean goods that are beneficial to people. An aggressive national war is technically a 'public good' in both the economic and political sense but it may not be good for people in the nation. In contrast, common goods are beneficial in a humanistic sense, and broadly beneficial (Marginson, 2016b). They contribute to shared social welfare, relations of solidarity, inclusion, tolerance, universal freedoms, equality, human rights and/or broadly distributed individual capability (Sen, 2000). Equality of opportunity in education is an example of a collective common good. In Mandarin Chinese lexicon, common goods are social goods that contribute to broad humanity (人类, Ren Lei). UNESCO (2015) has developed a notion of common goods in education, which can be provided by either public or private sector institutions. Another example is the British National Health Service, providing universal care free of charge, and deploying scarce resources so as to prioritize people in greatest need because of serious illness or accident. In Nordic countries, equal and solidaristic society is an end in itself and state policy emphasizes policies designed to secure common goods (Valimaa & Muhonen, 2018).

Common goods are collective public goods in the economic sense as they are necessarily non-market in character. As in the UNESCO definition, they are not always public goods in the political sense. Epistemologically, 'public' and 'common' have differing statuses. First, as noted, 'public goods' is a technical term for non-market goods, or state determined goods, that has no necessary normative meaning. The term 'common goods' refers to material relations and practices, that can be tracked empirically, but these practices also have a normative element. 'Common' is what people practice as joint, mutual, shared, to their common benefit. What is 'beneficial' is determined by the receivers of those benefits, working collectively. Second, and related to this, while many public goods are open to observation, regardless of viewpoint, common goods are more difficult to pin down and require further definition. Whether a good is state-produced or controlled, and whether or not goods are produced outside of markets, are not defined by values. But what is valued as 'common' is open to both interpretation and historical-political variation. While it is possible to devise an agreed list of indicators, the identification of indicators is (at least in part) a political and not solely technical process.

Locatelli (2018), working in the framework of the UNESCO discussion, states that 'the concept of education as a common good highlights the purposes of education as a collective social endeavour' (p. 11). She remarks that 'common good' can be understood as broader than 'public good'. While public goods are mostly 'linked to the functions and role of the state' (p. 3), with government provision and/or financing, this is not always true of common goods. Because 'common' is defined by the normative content of the activity, both government and non-government organization, including voluntary local cooperation (Ostrom, 1990), can contribute to common goods. However, 'some kinds of private participation are more defensible than others' (Locatelli, 2018, p. 8); and partial state funding and regulation ('public') may be needed to ensure commonality (p. 13).

2.3 *Global Public and Common Good(s)*

'Global' as used in this chapter refers not to the whole world and everything in it, but to phenomena, systems and relations that are planetary in scale, such as world ecology, or knowledge in mathematics (Marginson, 2010). 'Globalization' in higher education and other sectors refers to partial convergence and integration on the planetary or large regional (e.g. European Union) scale – from world markets and cross-border supply chains in industry; to networked banking and transport; to worldwide expansion of systems in communications, information and research; to cross-border migration of people; to open flows of ideas and knowledge.

Global Public Goods. In the late 1990s the United Nations Development Programme (UNDP), starting from issues of global ecology, defined global public goods as:

> …goods that have a significant element of non-rivalry and/or non-excludability and made broadly available across populations on a global scale. They affect more than one group of countries, are broadly available within countries, and are inter-generational; that is, they meet needs in the present generation without jeopardizing future generations. (Kaul et al., 1999, pp. 2–3)

UNESCO (2018c) includes as global public goods in education 'internationally comparative data and statistics', research on improvements in learning outcomes, and cross-border professional networks. It also notes that these goods are 'in short supply, poorly funded and rarely coordinated'. For the most part, global public goods are goods that are not adequately addressed by individual countries acting alone but require coordinated action. In the above quote, the UNDP emphasis on distributional equity ('broadly available') indicates a normative political rather than strictly economic definition of global public goods, taking the notion towards global common goods. Note that because there is no global state, only the economic definition of public goods is relevant. However, international agencies such the United Nations, the OECD and World Bank, operating as quasi global state organizations, attempt to shape values-based notions of the collective global interest.

Global Common Good (Singular). By global common good is meant the combined well-being and freedoms of humanity (人, Ren in Mandarin Chinese); that is, of human society and nations in the world as a whole. In Mandarin Chinese, the combined well-being might translate as 人类福祉 (Ren Lei Fu Zhi), though the combined well-being and freedoms might be better understood if spelled out in full as 人类福祉与自由 (Ren Lei Fu Zhi Yu Zi You).[3]

Global Common Goods (Plural). The term global common goods, plural, refers to shared relationships and benefits arising from higher education and research in cross-border relations, and at the level of the world as a whole, that are broadly accessible to different countries and people. For example, knowledge in mathematics, or the safety and security of mobile students. Global common goods are a sub-set of (non-market economic) public goods, that arise in the global sphere, in the combined global systems that make cross-border relations possible. As discussed in relation to common goods above, global common goods are more specific than collective public goods, in that they contribute to sociability, mutual capability, agency, freedoms, equality and rights. This commonality can be expressed in cross-border relations between countries or regions, between cities, between higher education institutions, and between individuals at any time.

Norms of commonality and their instruments, such as the climate change accords, the Universal Declaration of Human Rights, and the Sustainable Development Goals, which include commitments on tertiary education, are discursive global common goods. For UNESCO, education is not just a common good but a global common good (Locatelli, 2018). As discussed extensively below, the worldwide system of publicly accessible scientific knowledge is one of the most important of all global common goods, one that incubates many particular common goods, including the specific networks and knowledge in each academic discipline. Open communications and systems of free mobility between national higher education systems are other global common goods that establish a generic framework of global relations, with the capacity to foster many particular common goods. In a world in which networked inclusion continually expands (Castells, 2000), joining once separated localities together, people are more engaged with others and this creates an expanding potential for common goods in global civil society. Platform capitalist networks such as Google can facilitate – and distort – the evolution of collaborative common goods.

2.4 *Common Goods in Higher Education*

What common goods are produced in research-intensive universities?

Individual and Collective Benefits. Figure 2.2 provides a way of comprehending all of the contributions of higher education – a map of the contributions of WCUs, individualized and collective, in the national/local and global dimensions. Higher education contributes to relational society in many ways. All four categories include potential common goods (in bold type) that contribute to shared social welfare, solidarity, inclusion, tolerance, equality, universal freedoms, human rights and/or the broad advance of capability. Only some of the possible common goods are listed: higher education also augments intercultural relations, foster tolerance of difference, widens political participation, and so on (McMahon, 2009).

The global collective benefits of higher education in Cell 3, generated in common through relationships than span the different national borders, include the knowledge system, disciplinary cultures, communications, mobility and cross-cultural exchange. Research collaboration on common global challenges lifts WCUs above their more localised and captured functions as engines of national and individual prosperity, advantage and prestige. As remarked by Patrick Aebischer, President of the École Polytechnique Fédérale de Lausanne:

> Universities have become institutions of a global world, in addition to assuming their traditional local and national roles. The answers to global challenges (energy, water and food security, urbanization, climate change, etc.) are increasingly dependent on technological innovation and the sound scientific advice brokered to decision-makers. The findings contributed by research institutes and universities to the reports of the Intergovernmental Panel on Climate Change and the Consensus for Action statement illustrate the decisive role these institutions are playing in world affairs. (Aebischer, 2015, p. 3)

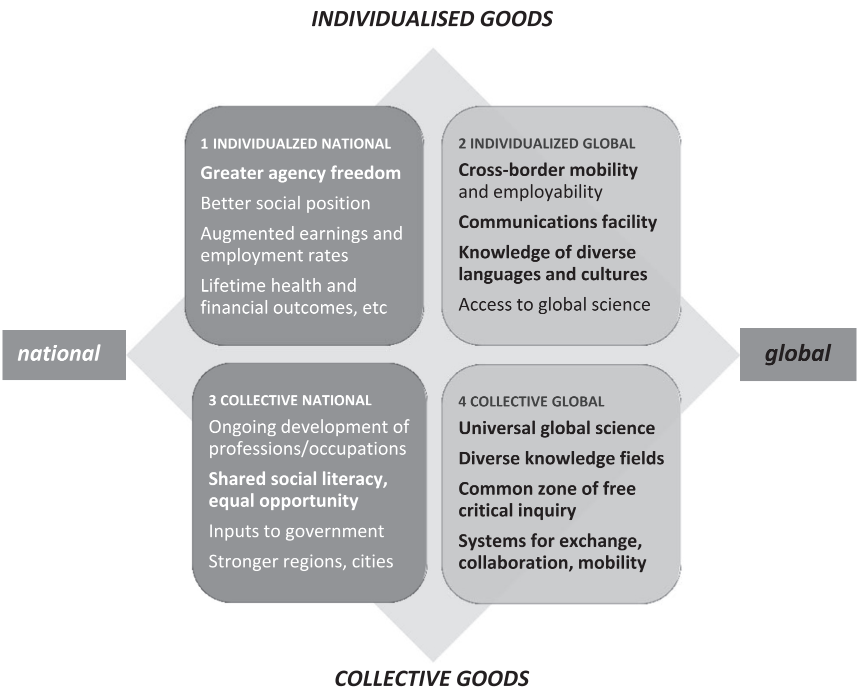

FIGURE 2.2 Examples of individualized and collective contributions of higher education

The same WCUs that compete against each other in vertical rankings also work together horizontally. This does not mean that competition and collaboration (or national and global activities) join neatly in seamless fashion. There are synergies, but also tensions and closures. In global higher education and research, the common good is by no means always uppermost. Nevertheless, the expansion of worldwide research networks means that the potential global commons has been fundamentally expanded.

Discussion of the benefits of higher education often focuses on Cell 1, the individualized national goods, especially the graduate employment rates and lifetime salary benefits associated with degree-holding. Cross-border individualized benefits (Cell 2) are mostly treated as marginal to the national benefits; and the collective benefits of higher education (Cells 3 and 4), which are more difficult to observe and measure, are even less recognized. It is true that higher education is a process of self-formation (Marginson, 2018a) that augments a person's capabilities and opportunities. This includes career and financial benefits. But Cell 1 also includes many more individualized effects, most of them non-pecuniary, as is suggested by Biesta's (2009) trio of qualification, socialization and subjectification. And moving beyond Cell 1 there is much more to higher education than its direct effects for students. The direct effects on graduates indirectly affect the people with whom graduates live and work, and flow into the institutions, systems and languages of complex societies. Education forms people in social relations on a large scale. It is both formative of society and continually formed by society. Individual people develop and exist only on a relational social basis. The individual *always* presumes the social, and vice versa (Vygotsky, 1978; Dewey, 1927). In social science it is absurd to model higher education as if it produces only autarkic individuals. Yet that is what is suggested by the economic policy focus that confines higher education to individual economic benefits.

Here the normative dimension of common goods matters. It affects behaviour. If students, graduates and families are told by political leaders and public media that the main (if not the sole) goal of higher education is their own socio-economic benefit as individuals, all else being equal those graduates will be less community minded – less committed to the common good – than if they are told their higher education should and does benefit the whole society. Further, if higher education's sole purpose is graduates' private advantage, non-graduates outside higher education have no stake in it. This opens up higher education to a populist challenge. If the purpose of higher education institutions is simply to generate the highest possible graduate rates of return, then all its institutions, especially WCUs, are rightly charged with elitism. On the other hand, if higher education is seen as the source of a range of common goods, and graduates are expected to contribute to the betterment of society, as in the Kantian/Humboldtian idea of the university, then WCUs will be held to account for those common goods, in which whole populations have a stake. In short, if WCUs are treated as a shared resource in which all have a stake, then common goods are more likely to result.

Global Common Goods in Higher Education. WCUs produce three kinds of global common goods. First, they help people to form global relational competences – knowledge, skills and sensibilities enabling them to act across national and cultural boundaries. Second, they are a fecund zone of cross-border mobility and mixing of people, particularly research-intensive faculty, doctoral students and university leaders. Third, as 'thickly' networked institutions they constitute a space for conversations of two kinds: knowledge-forming conversations in the academic disciplines, and more generic conversations on matters of the day. In of all these ways WCUs are more globalized than the national-local societies in which they sit.

Global Attributes of Individuals. Learning and work in higher education are associated with enhanced individual capacity to travel, in two respects: capability in physical travel, and capability in information and communications technologies (ICT), cross-border electronic sociability, the capacity to travel electronically across the earth. The extent to which these attributes are engendered by higher education or due to other individual characteristics such as cognitive capability, geographic location, or family income or social capital, cannot be settled here. But it is safe to assume that higher education matters. There is marked variation between graduate and non-graduates in the capacity to travel, in both respects.

For example, in its 2012 Survey of Adult Skills the OECD generated data on ICT-related skills according to educational qualification. Of 25–64 year-olds with tertiary qualifications, 52 per cent had 'good ICT and problem-solving skills'. Only 7 per cent had 'no computer experience' or refused an ICT skill test. Of those with upper secondary or non-tertiary post-school education, 25 per cent had good skills while 21 per cent had no experience or refused the test. Among those with lower secondary or below, seven per cent had good skills and 47 per cent had no experience or refused the test. These patterns held across the 22 countries and parts of countries that supplied survey data (OECD, 2015, pp. 46–47).

Likewise, the average graduate is more at ease than is the non-graduate with physical cross-border mobility. In *Perspectives on Global Development 2017: International migration in a shifting world* (OECD, 2016, p. 32) the OECD compares migration among people with, and without, university degrees. For those without degrees the tendency to migrate is correlated to income. As income

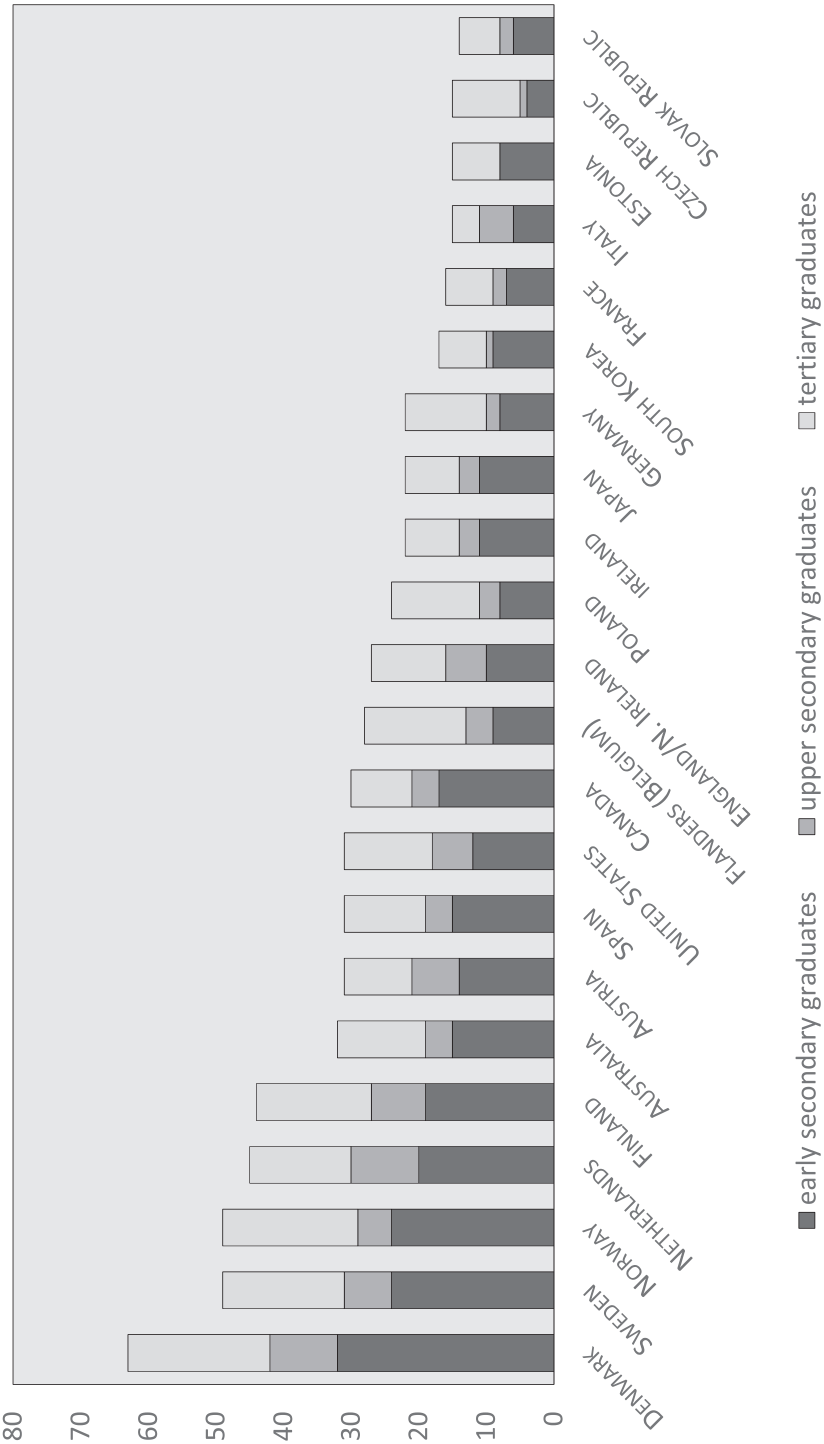

FIGURE 2.3 Proportion (%) of people answering 'yes' to the question 'do you trust others?' OECD nations, 2012 OECD survey of adult skills

rises people are more likely to move. Among those with degrees the pattern is different. As income rises, once a modest threshold level is reached there is little change in mobility. It becomes income inelastic. In helping graduates to greater personal agency in this domain, mobility, higher education weakens the effects of economic determinism on their imaginings, choices and decisions. Here as in other ways degree level education directly constitutes greater personal freedoms. If mobility across borders is a human right – the right to control where one's body moves across the earth – then higher education enhances access to that right. Further, in boosting the capacity for mobility, higher education expands relational society, which is another common good.

One reason that graduates find it easier to travel is that they are more confident in dealing with others. The OECD Survey of Adult Skills also includes data on the proportion of people who said that they 'trust others'. As education level rises people are more likely to trust others (Figure 2.3). In Denmark, Norway, Sweden and Finland, which have a solidaristic social model, the level of trust is relatively high for all people but much higher among graduates: almost half of all Nordic tertiary graduates say they 'trust others' compared to a quarter of those who left school in the early secondary years (OECD, 2015, p. 163). While the OECD survey did not ask directly about trusting foreigners, these data again suggest that graduates may have comparatively advanced capabilities in cross-border social relations.

In both the formal curriculum and the experience of cosmopolitan university settings, higher education also helps to form other Cell 2 (Figure 2.2) relational attributes that facilitate global mobility, communication and understanding, such as language skills, knowledge of other countries, and cultural tolerance. These attributes are enhanced by actual cross-border experiences, 'internationalization' abroad and at home, as testified in an extensive literature (e.g. of many Deardorff, de Wit, Heyl, & Adams, 2012). Prolonged and varied experiences abroad quicken the person's flexibility in the face of difference and change. They heighten confidence, proactivity, awareness of one's identity – or in other words, reflexive self-determining 'agency freedom' (Marginson, 2014). Cross-border mobility and internationalization at home tend to be more prevalent in WCUs than other higher education institutions. This is a function of the institutional resources of WCUs, the socially elite character of many of their students, and the extent to which WCUs are globally networked in research and partnerships and subsidized for inward and/or outward travel.

In the Erasmus programme in Europe, WCUs provide many of their students with cross-border experience, though with a small number of exceptions (e.g. the National University of Singapore) WCU student mobility outside

Europe is lower. Overall, with some exceptions, WCUs have more cosmopolitan faculty populations than other institutions. In certain leading English-speaking WCUs, half or more of faculty are foreign born.

Global Mobility System. Networked higher education institutions and national administrations form a common informal system facilitating ease of academic movement across borders. This mobility system (Cell 3 in Figure 2.2) enables students and staff to acquire individualized global goods (Cell 2), not only global attributes and greater agency freedom but often, better career opportunities and incomes. Mobility is facilitated by a complex, evolving lattice of one-to-one and multilateral cooperative agreements; partnerships and university consortia; multi-country and localized mobility schemes for students and faculty, as noted (e.g. Erasmus, the China Scholarship Council programmes); and accreditation and recognition protocols, including interlocking quality assurance arrangements. The only comprehensive data on cross-border mobility are for student stays of one year or more (UNESCO, 2018a). Some countries, including China and the US, collect data on shorter incoming student stays. Many countries track outward student stays. Data on long-term faculty movement are patchy. Some countries collect data on foreign staff recruitment – one indicator of the global openness of national higher education systems – but there is no global compilation.

Between 1995 and 2011, the worldwide number of cross-border students increased rapidly, from 1.7 to 4.4 million. After 2011 growth slowed to 4.6 million in 2015, though there were also 13 million cross-border online students (OECD, 2017, p. 295). One driver of growth is commercial international education in the UK, Australia and New Zealand. This fosters some instances in WCUs of very large cross-border student enrolment. These WCUs use surplus generated from international students to part-finance research. For example, the University of Melbourne in Australia, which was positioned at 39th in the ARWU in 2017, had 13,200 effective full-time international students in 2014 – 29.1 per cent of student load – who paid US$224.5 million in fees (DET, 2018). In the UK, University College London enrolled 4,470 full-fee non-European Union international students in 2016–2017, 11.8 per cent of all students (HESA, 2018). In the United States, international education in WCUs is less commercial, and WCUs mostly have lower international student volumes, but in 2015–2016, there were 13,340 international students (8.2 per cent) at the University of Southern California (IIE, 2017). China is becoming a major provider for international students (OECD, 2017), with growth of student numbers, as in the US, driven more by foreign policy objectives and university internationalization strategies rather than by revenues. China is currently expanding scholarship aid to 'Belt and Road' emerging countries in Asia and Africa.

International students constitute 4.3 per cent of all first-degree students in OECD countries and 11.5 per cent at Masters level but a large 25.7 per cent at doctoral level (OECD, 2017, p. 300). 'Mobile students gain tacit knowledge that is often shared through direct personal interactions and that enables their home country to integrate into global knowledge networks…students' mobility appears to more deeply shape future internal scientific cooperation networks than a common language, or geographical or scientific proximity' (p. 287). Mobile doctoral students and researchers augment the reputations and revenues of WCUs. At the same time rankings articulate the global competition for talent, magnifying the attractiveness of strong systems and WCUs. Talent flows are skewed in favour of the leading countries with WCUs, though as Table 2.2 shows, mobile doctoral students play a varying role in those countries – large in the United Kingdom, United States and Netherlands; more modest

TABLE 2.2 Internationally mobile or foreign doctoral students as a proportion (%) of all doctoral students in 2015, OECD systems, Brazil and Russia, compared to number of ARWU top 500 universities in each country in 2015 (number of top 500 universities in brackets)

Country	Proportion international or foreign %	Country	Proportion international or foreign %	Country	Proportion international or foreign %
Luxembourg (0)	87.0	Austria (6)	27.0	Slovak R.[a] (0)	9.1
Switzerland (7)	54.3	**OECD average**	**25.7**	Latvia (0)	8.8
New Zealand (2)	46.2	Ireland (3)	25.4	S. Korea[a] (12)	8.7
UK (37)	42.9	Canada (20)	24.4	Slovenia (1)	8.5
Belgium (7)	42.3	Brazil[a] (6)	22.4	Chile (2)	8.4
France (22)	40.1	Portugal (3)	21.2	Hungary (2)	7.2
US (146)	37.8	Norway (3)	20.5	Turkey[a] (1)	6.5
Netherlands (12)	36.2	Finland (6)	19.9	Israel[a] (6)	5.5
Sweden (11)	34.0	Japan (18)	18.2	Russian F.[a] (2)	4.5
Australia (20)	33.8	Czech R.[a] (1)	14.8	Mexico (1)	2.6
Denmark (5)	32.1	Estonia (0)	10.7	Poland (2)	1.9
Iceland (0)	31.6	Germany (39)	9.1		

[a]Foreign citizen students (including long-term residents) and not just internationally mobile students.

SOURCE: AUTHOR USING DATA FROM OECD (2017, P. 300) AND ARWU (2018) in Canada and Japan; relatively minor in Germany, Israel and Korea. Switzerland has more international doctoral students than nationals. The STEM disciplines play the largest part in doctoral mobility. In 2015, 28 per cent of mobile doctoral students were working in natural sciences and mathematics; 25 per cent were in engineering, manufacturing and construction; and 6 per cent in ICTs research (p. 289).

The United States, where 37.8 per cent of all doctoral students are international, takes in much the largest group in quantity terms (OECD, 2017, p. 288). US research in STEM is highly dependent on internationally mobile doctoral students, especially from Asia. National Science Board (NSB) data shows that between 1995 and 2015 there were 166,920 Asian recipients of doctorates in the United States who studied on temporary visas, including 68,379 from China, 63,576 (93.0 per cent) of them in STEM fields; and 32,737 from India, 30,251 (92.4 per cent) in STEM (Table 2.3) (NSB, 2018, tables 2-14 and 2-15). Many student source countries have a net loss of talent. PhD graduates often stay where they are educated, especially the US with its large pool of work opportunities – though these graduates often maintain networks in their home countries and many return or circulate later in their careers. Of American doctoral recipients in 2012–2015 from China, 83.4 per cent had plans to stay and 49.4 per cent had definite plans. The stay rate was highest in mathematics and computer science (NSB, 2018, table A3-21).

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Networked Global Research and Free Inquiry. As noted, WCUs sustain an expanding worldwide space for research inquiry, other academically codified thought, and the dissemination of scholarship. Wagner, Park, and Leydesdorff (2015, p. 1) find 'science has become increasingly collaborative and team based', and 'a growing percentage of these collaborations happen at the international level'. The global science, data storage/transfer and publishing systems; official national and WCU strategies that foster internationalization (a goal in itself for most national systems and almost every WCU) (Altbach & Salmi, 2011); the culture of collaboration, that fosters bottom-up disciplinary exchanges in each science and non-science – together they constitute not only a vast joined up machine for intellectual production, but a shared space for free inquiry on the global scale, a world mind, free to inquire collaboratively, that spreads and deepens along with the spread of WCUs.

Global Civil Society. Networked WCUs also support a larger joined up conversation, unevenly rooted from place to place but with its own discernible global character, in which the emblematic modes of communication are reasoned argument and evidence-based truth. Again with some local variation, there is a shared commitment to the virtues of free discussion, reflexive social criticism, balanced modernization, poverty alleviation, ecological sustainability, universal education, cosmopolitanism and human rights. This university-orchestrated public culture – one this is critically opposed to the ubiquitous marketing discourse, to fake political news and to other forms of 'post-truth' – draws definition from global science and the widely understood Humboldtian

TABLE 2.3 Recipients of United States doctorates on temporary visas, by country/region of origin (four largest country/regions) by science-based discipline, 1995–2015

Disciplinary field	China Mainland & Hong Kong SAR	India	South Korea	Taiwan
Engineering	23,101	13,208	8274	5045
Physical sciences	10,816	3516	2216	1305
Computer sciences	4229	2477	1015	597
Mathematics	4493	805	967	503
Earth, atmospheric and ocean sciences	1563	357	338	228
Biological sciences	12,202	5654	2459	2374
Medical and health sciences	1368	1371	672	878
Agricultural sciences	1745	823	720	441
Psychology	530	277	481	320
Social sciences	3529	1763	3484	1310
All other fields	4803	2486	3484	3618
Total	68,379	32,737	26,630	16,619

SOURCE: DATA FROM NSB (2018, TABLE 2-15) idea of the university, including notions of university autonomy and academic freedom (Rohstock, 2012). Blending into national and global civil society, this kind of public culture takes in a large population of the university-educated and university-touched, though societies and polities vary in the extent to which they encourage public forms of intellectualism.

3 Global Science, Network Logic and WCUs

The key to explaining the development of the world research system, its rapid growth, pluralization and patterns of collaboration, is the dynamics of network formation. As Wagner and colleagues note: 'Given the growth of connections at the international level, it is helpful to examine the phenomenon as a communications network and to consider the network as a new organization on the world stage that adds to and complements national systems…The network has features [of] an open system, attracting productive scientists to participate in intellectual projects' (Wagner et al., 2015, p. 1).

Open network structure. In a network structure, new agents freely join the network at negligible cost. Each existing node gains from the addition of each new node, and the potential linkages continually multiply, so that productivity advances continually and the network tends towards universal coverage (Castells, 2000). In higher education and research, there is a continuing multiplication of projects, collaborations and synergies. Cross-border people mobility in higher education, and WCUs' intrinsic contributions to international engagement, tolerance and understanding, also augment the potential for collaboration.

In their study of the development of the global science network after 1990, Wagner and colleagues (2015) state that they 'expected to find a tight core group – meaning a group of frequently interacting countries – with less developed countries falling into a periphery around a core', as found in earlier studies of the global network. They also 'expected high betweenness measures – meaning that some countries have greater visibility and power within the network to attract others into collaborative relationships' (p. 5). What they found instead was a vast expansion of the number of countries in the 'dense centre of the network'. The 35 countries in 1990 expanded to 64 in 2005 and 114 in 2011, 'with many developing countries also joining the core group […] new members find it relatively easy to join' (p. 6). This coincided with a doubling in the number of countries investing in R&D at scale (p. 7). 'This growth suggests that most nations have scientists who are participating actively in international collaborative networks […] capacity building has enabled researchers in many more countries to collaborate' (pp. 6–7).

Despite growth in total network size the average distance between countries has diminished and network diameter remains at three. The whole network is traversed in three steps, from a node on one edge of the network to a node on the other edge. Further, 'the average betweenness among nations has dropped', substantially, 'suggesting fewer nodes dominate the network, or, in other words, power is more diffused throughout the network in 2011 than was the case in 1990' (p. 6).

Importantly, 'new entrants are not clustering around the scientific 'leaders', suggesting 'a more open network than was found in 1990' (Wagner et al., 2015, p. 6). 'Many nodes operate effectively in the network' (p. 7). 'New entrants are able to find collaborators without having to pass first through a core of highly powerful (or central) nodes'. Science 'may be operating as an open system' (p. 8). The more open system of global science is also more pluralized. Network structure and agency both facilitate this. 'Many more connections have been forged by more partners [...] The increase in links is disproportionately large compared to the growth in the number of addresses in the file' (p. 6), consistent with the numerical growth in co-authored papers (p. 6). The science network 'has grown denser but not more clustered, meaning there are many more connections, but they are not grouped together in exclusive "cliques"' (p. 1). Relations of power within global science are 'not recreating political or geographic structures' (pp. 1, 6). 'Power is being dispersed throughout the network' (p. 6). This in turn has implications for the relationship between science, the WCUs that house it, and the nation-state:

> As international collaboration has grown, it is possible to argue that the shift towards the global challenges the relationship between science and the state. Collaboration has grown for reasons independent of the needs and policies of the state. Reasons for the growth of collaboration appear to be related more to factors endogenous to science. (Wagner, Park, & Leydesdorff, 2015, p. 1)

3.1 *Growth of Published Science*

Table 2.4 lists all of the countries that produced more than 10,000 papers in 2016. Between 2000 and 2016 published science grew by 3.9 per cent per annum at world level. Most of the mature research systems are on the right side of the table, with slower growth. On the left side, China had annual growth of 8.4 per cent and India 11.1 per cent. Iran moved from 10,703 to 40,974 papers, annual growth of 15.1 per cent. Malaysia achieved 20,332 papers in 2016, and exceptional 20.2 per cent annual growth, though from a low base. Just below 10,000 is Saudi Arabia (9232 papers, 17.1 per cent annual growth). In the

TABLE 2.4 Annual rate of growth in published science papers, 2006–2016, nations producing more than 10,000 papers in 2016

System	Papers 2006	Papers 2016	Annual growth %	System	Papers 2006	Papers 2016	Annual growth %
Malaysia	3230	20,332	20.2	Italy	50,159	69,125	3.3
Iran	10,073	40,974	15.1	Singapore	8205	11,254	3.2
Romania	3523	10,194	11.2	Austria	9155	12,366	3.1
India	38,590	110,320	11.1	Spain	39,271	52,821	3.0
Egypt	3958	10,807	10.6	Switzerland	16,385	21,128	2.6
Mainland China	189,760	426,165	8.4	Belgium	13,036	16,394	2.3
South Africa	5636	11,881	7.7	Germany	84,434	103,122	2.0
Russia	29,369	59,134	7.2	Netherlands	24,461	29,949	2.0
Portugal	7136	13,773	6.8	Sweden	16,634	19,937	1.8
Brazil	28,160	53,607	6.6	Canada	49,259	57,356	1.5
Czech Republic	8839	15,963	6.1	Finland	9204	10,545	1.4
South Korea	36,747	63,063	5.5	France	62,448	69,431	1.1
Denmark	8536	13,471	4.7	United Kingdom	88,061	97,527	1.0
Poland	21,267	32,978	4.5	Taiwan	25,246	27,385	0.8
Mexico	9322	14,529	4.5	United States	383,115	408,395	0.7
Australia	33,100	51,068	4.4	Israel	11,040	11,893	0.7
Norway	7093	10,726	4.2	Greece	10,684	10,725	0.0
World	1,567,422	2,295,608	3.9	Japan	110,503	96,536	−1.3

SOURCE: BASED ON NSB (2018, TABLE 5-22)

world's fourth largest country by population, Indonesia, now a middle-middle income country, science has begun a long upward climb, moving from 619 to 7729 papers (an annual growth rate of 28.7 per cent) (NSB, 2018, table 5–22).

More productive WCUs. Between 2009 and 2015, the number of individual universities producing more than 1,000 science papers in the previous four years rose from 685 to 903. The number producing over 5,000 papers rose from 126 to 190. The number of very large science engines publishing over 10,000 papers doubled from 25 to 50. The number of universities producing high citation science also grew, as did the average number of high citation papers produced by the leading universities. (The number of papers in the top 10 per cent of their field by citation rate grows automatically in proportion to total output.) In 2009, 138 WCUs had more than 500 papers in the preceding four years that were in the top 10 per cent category. By 2015 that number had risen to 211 WCUs (Leiden University, 2018).

3.2 *Pluralization of Science*

Between 2006 and 2012 there was a modest pluralization of WCUs in national terms. Using a relative definition of WCU, from 2004 to 2017 systems with top 500 universities increased from 37 to 46 (ARWU, 2017). Using an absolute definition of WCU, the number of countries with universities producing over 5,000 science papers in the previous four years rose from 23 countries in 2009 to 27 in 2015. Universities with more than 5,000 papers not from the US or UK rose from 54.0 to 62.1 per cent. There was also greater plurality of high quality papers.

Rise of East Asia and Singapore. Within the overall global pattern of growth and dispersion of research capacity, the most important trend is the rise of East Asia and Singapore (the geographical outlier of the Chinese civilizational zone) to third major R&D region, joining North America and Western Europe/UK. In 2003, China produced less than 30 per cent of US scientific output but it reached first place in 2016 (Figure 2.4). China's number of papers multiplied by 4.9 in 13 years, South Korea's output by 2.7. Meanwhile the number of ARWU-defined WCUs in mainland China grew from eight of the top 500 in 2005, to 45 in 2017 (ARWU, 2017). (China's and Singapore's WCUs would be more highly placed if the ARWU did not use Nobel Prizes as an indicator). The pipeline effects of current national investments ensure that in China and Singapore, and probably in South Korea, scientific output will continue to grow rapidly for years to come, even if budgets stopped increasing tomorrow (they won't). China's science will be twice further boosted, by the 'Double World-Class' project and activity with the 'One Belt One Road' initiative.

Turning from quantity indicators to quality, Figure 2.5 traces changes in six countries from 1996 to 2014 in the proportion of all science and engineering papers that were in the top one per cent of their disciplinary field on the basis of citation rate. In all countries shown there was growth in the weight of the top one per cent papers. The US, the world leader in 1996, moved from 1.75 to 1.90 per cent. In 2005, it was passed by the Netherlands, one of the small-to-medium-size high quality science systems in north-western Europe. In 2011 the US was passed by the UK, which has concentrated research excellence in leading universities through successive iterations of the Research Assessment Exercise/Research Excellent Framework. Over the period European countries, including the UK, benefitted from the collaborative building of research

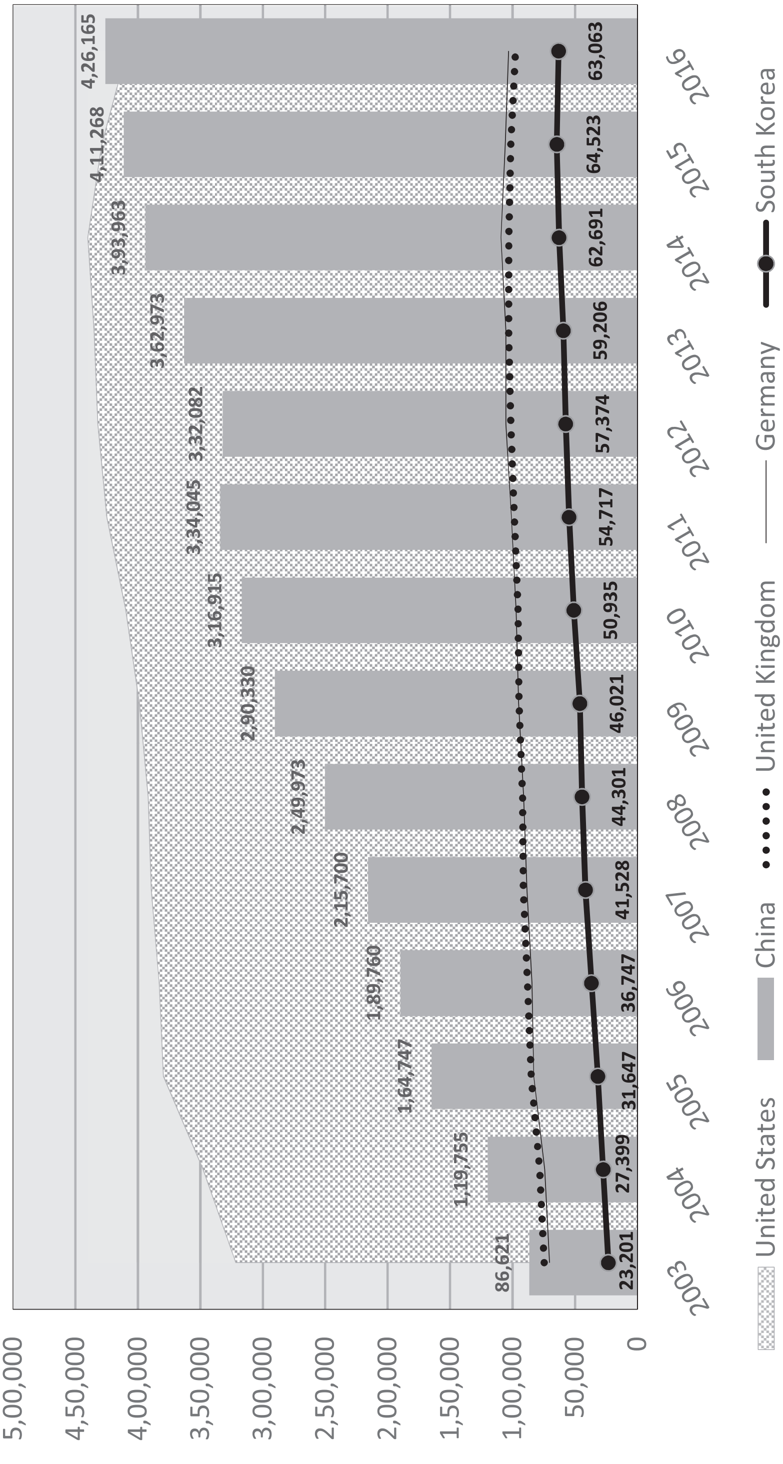

FIGURE 2.4 Annual number of published science papers, 2003–2016 United States, China, Germany, United Kingdom, South Korea

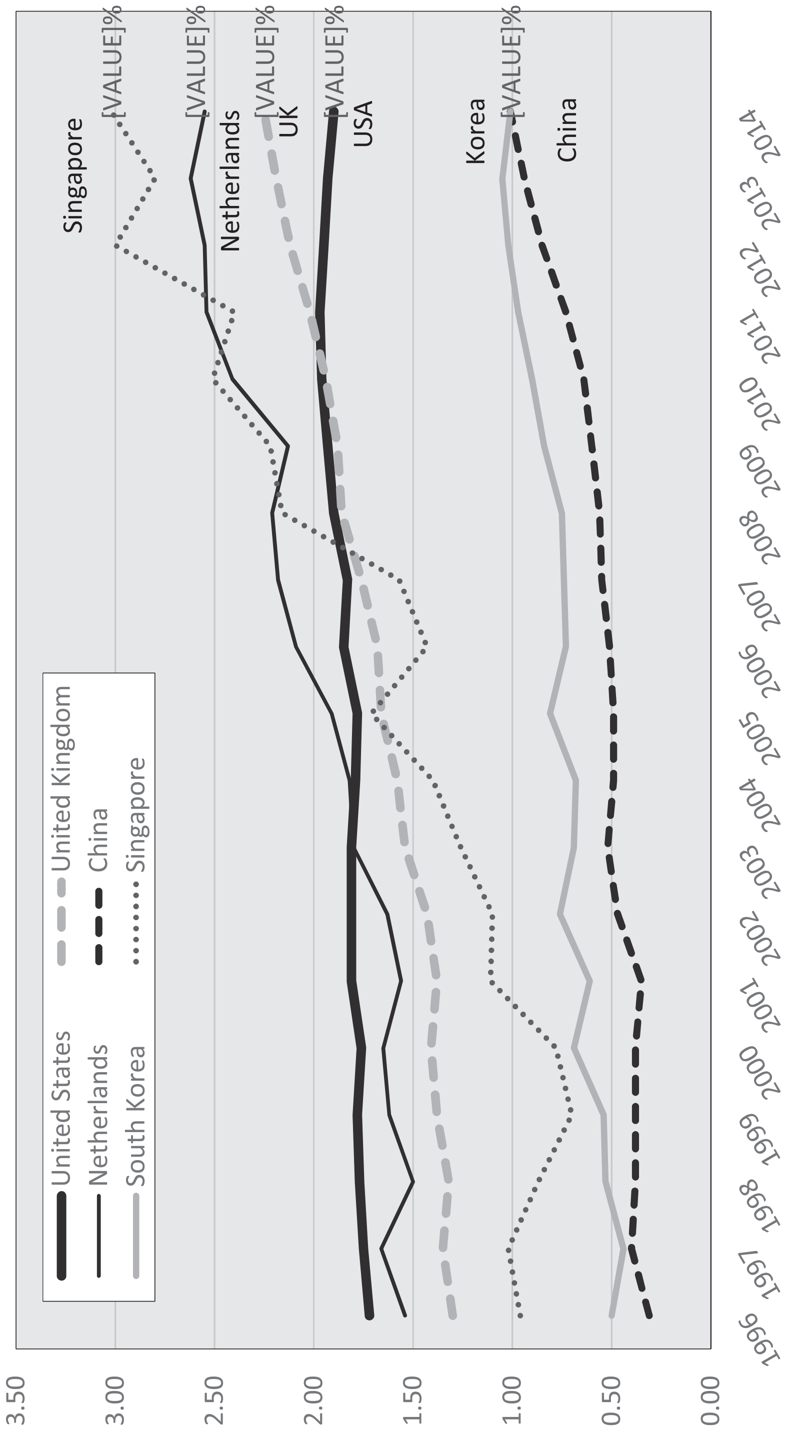

FIGURE 2.5 Proportion of all science and engineering papers that were in the top 1 per cent of their field by citation rate: United States, United Kingdom, Netherlands, China, South Korea, Singapore: 1996–2014

in European Research Area joint programmes. Many smaller European countries, with a cluster of WCUs and nuanced specializations, had more than 1.90 per cent of their 2014 papers in the top one per cent: Austria, Belgium, Cyprus, Denmark, Estonia, Finland, Greece, Iceland, Ireland, Norway, Sweden, Switzerland. In larger Germany the proportion was 1.76 per cent, in France 1.61 per cent (NSB, 2018, A5-51).

The other story in Figure 2.5 is the improvement of quality in East Asia. As in the English-speaking countries, qualitative improvement shows more strongly in the form of increases in top one per cent science, than in increases in average citations to all papers, indicating WCU concentration policies at work. Tiny Singapore with less than six million people lifted the proportion of its papers that were in the top one per cent from 0.70 per cent in 1999 to 3.02 per cent in 2014, three times the world average. South Korea reached world average level in 2012; China with 1.3 billion people climbed from only 0.31 per cent in 1996 to reach world average in 2014. Science in China is still well below the average quality of Western Europe and the US but the massive scale of the national system, coupled with rapid growth in high citation work in some disciplines, means that a large proportion of the world's future knowledge will come from that country.

Physical sciences STEM in East Asia. What about individual WCUs? Table 2.5 summarizes the growth of top 10 per cent papers in leading WCUs in East Asia and Singapore, compared to MIT and Cambridge. At Zhejiang, Peking, Fudan and Huazhong in China, and Nanyang in Singapore, the dynamism is obvious. The performance of smaller Nanyang is approaching that of NUS in Singapore.

Table 2.6 lists the world's top 15 WCUs in physical sciences STEM, in terms of papers in the top 10 per cent by citation rate in 2012–2015. China had eight of the leading 15 universities in mathematics and computing. Tsinghua was far ahead as world number 1 with Nanyang in Singapore in second place. In the larger physical sciences and engineering group, Berkeley and MIT were the top two. US and China both had five of the top 15. Combining the two columns in Table 11, Tsinghua with 1,421 papers just shades MIT with 1,420 papers as the world's top physical sciences STEM university – though the US still had four of the top seven WCUs. If the measure is switched to the much smaller group of top one per cent papers, MIT is top in combined physical sciences STEM, followed by Stanford, Berkeley, Harvard and Nanyang, all ahead of Tsinghua. However, Tsinghua is clear world number one in top one per cent papers in mathematics and computing alone (Leiden University, 2018).

Discipline imbalance. However, when all disciplines are included in the comparison, American WCUs as a group are well ahead of the world in the quantity of high quality work, and like European universities more balanced

TABLE 2.5 Growth in the number of published papers in the top 10 per cent of their research field by citation rate, from 2006–2009 to 2012–2015, selected leading Asian universities

University	System	Top 10% papers 2006–2009	Top 10% papers 2012–2015	Growth 2006–2009 to 2012–2015 2006–2009 = 1.00
Tsinghua U	Mainland China	819	1768	2.15
Zhejiang U	Mainland China	730	1762	2.42
Peking U	Mainland China	622	1538	2.47
Shanghai Jiao Tong U	Mainland China	644	1403	2.11
Fudan U	Mainland China	469	1224	2.61
Huazhong UST	Mainland China	241	1045	4.37
National U Singapore	Singapore	1042	1597	1.53
Nanyang Technological U	Singapore	568	1413	2.49
Tokyo U	Japan	1323	1333	1.01
Kyoto U	Japan	968	932	0.96
U Hong Kong	Hong Kong SAR	558	741	1.33
Seoul National U	South Korea	742	1182	1.59
National Taiwan U	Taiwan	604	786	1.30
MIT	US	2091	2565	1.23
U Cambridge	UK	1796	2274	1.27

SOURCE: BASED ON LEIDEN UNIVERSITY (2018) DATA

than their newly emerged East Asian counterparts. Research systems in China, Singapore, Korea and Japan are skewed to physical sciences STEM, less strong in biological sciences and weak in medical sciences, and (less surprisingly) in English language social sciences and humanities. In the last disciplines the global comparison means less because most work is in national languages. China is an extreme case of the discipline skew. In 2016, 49.6 per cent of all papers by researchers from the United States were in medical sciences biological and other life sciences, excluding agriculture (29.3 per cent in medical research alone). In the European Union (EU) the combined proportion in medical, biological and other life sciences was 40.7 per cent. In China, the combined proportion in those disciplines was 27.5 per cent. Only 13.3 per cent of all papers were in medical research, less than half the US level. In the United States 10.7 per cent of papers were in quantitative social sciences and psychology, in the EU 10.1 per cent but China 1.3 per cent (NSB, 2018, table 5–23).

TABLE 2.6 World top universities in (1) physical sciences and engineering, (2) mathematics and complex computing, in published papers in the top 10 per cent of their field by citation rate: 2012–2015

	University	System	Top 10% papers in Physical Sciences & Engineering 2012–2015		University	System	Top 10% papers in Maths & Complex Computing 2012–2015
1	UC Berkeley	US	1176	1	Tsinghua U	Mainland China	367
2	Massachusetts IT	US	1175	2	Nanyang TU	Singapore	259
3	Tsinghua U	Mainland China	1054	3	Zhejiang U	Mainland China	256
4	Stanford U	US	976	4	Huazhong US	Mainland China	250
5	Nanyang TU	Singapore	931	5	Massachusetts IT	US	245
6	Harvard U	US	875	6	Harbin IT	Mainland China	236
7	Zhejiang U	Mainland China	857	7	NU Singapore	Singapore	226
8	U Cambridge	UK	801	8	Stanford U	US	208
9	NU Singapore	Singapore	749	9	Xidian U	Mainland China	205
10	U S & T	Mainland China	720	10	Shanghai Jiao TU	Mainland China	196
11	ETH Zurich	Switzerland	678	11	City U Hong Kong	HK SAR	188
12	U Tokyo	Japan	649	12	U Texas, Austin	US	187
13	Shanghai JT U	Mainland China	638	13	South East U	Mainland China	184
14	Peking U	Mainland China	636	14	UC Berkeley	US	184
15	Caltech	US	635	15	Beihang U	Mainland China	177

SOURCE: BASED ON LEIDEN UNIVERSITY (2018) DATA

Leiden University (2018) data show that in the number of top 10 per cent papers in biomedical and health sciences in 2012–2015, the highest ranked Chinese university was Shanghai Jiao Tong at 117th. The leader, Harvard, had 726 high citation papers in biomedical and health sciences. Shanghai Jiao Tong had just 30.

3.3 *Global Collaboration in Research*

Cross-border collaboration can be examined in terms of both national level data on cross-border collaboration and citation, and data on collaborative publication by individual WCUs.

The world picture. The number of jointly authored publications is expanding rapidly (see Figure 2.6), and their proportion of all published science also grows (Figure 2.6, Table 2.7). Cross-national citation of papers is also increasing, suggesting that on average, published research in each country has a growing influence on researchers in other countries. Nevertheless, the patterns of cross-border collaboration in publications and cross-border border citation are uneven between disciplinary fields and vary between countries.

The disciplines vary in the extent to which work is internationally authored. Collaboration increases where there are formal programmes, especially when necessary equipment is cost shared (e.g., telescopes, synchrotrons) or subject matter is intrinsically global (e.g., climate change, water management, energy security, epidemic disease). In 2016, cross-border authorship was 54.0 per cent of published papers in astronomy and exceeded 20 per cent in the geosciences, biological sciences, mathematics, physics and chemistry. Between 2006 and 2016 it rose in every discipline, including engineering from 13.7 to 17.7 per cent and social sciences from 11.4 to 15.4 per cent (NSB, 2018, p. 122).

Using Web of Science data, Wagner and colleagues (2015) find that at world level the proportion of all papers that had international co-authors rose from 10.1 per cent in 1990 to 19.5 per cent in 2000 and 24.6 per cent in 2011. Jointly-authored papers 'account for all the growth in output among the scientifically advanced countries', and emerging countries are playing a growing role in collaboration (p. 1). Using the Scopus data set, the US National Science Board (NSB) finds that the number of internationally co-authored papers rose from 194,398 in 2003 to 498,465 in 2016, moving from 16.3 to 21.7 per cent (Figure 2.6). Domestic-only collaboration held steady and there was a proportional decline in single authored papers. Cross-border papers multiplied by 2.6 while total papers multiplied by 1.9. American internationalization followed the world trend. US Papers with international collaborators advanced from 23.3 to 37.1 per cent (Table 2.7) (NSB, 2018, table A5-42).

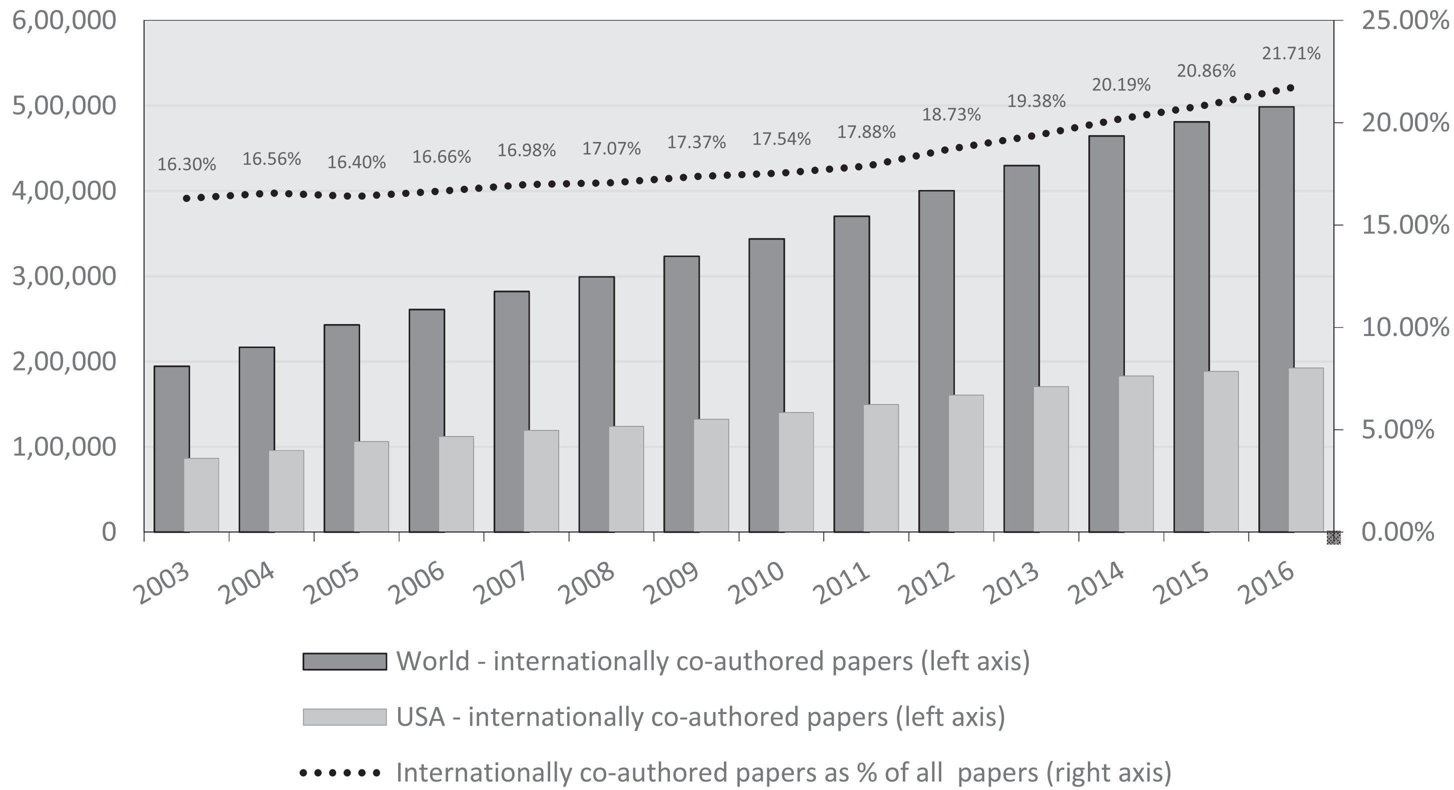

FIGURE 2.6 Growth in annual number and proportion of internationally co-authored papers in science and engineering, 2003 to 2016, world and United States

TABLE 2.7 Proportion of all papers in science and engineering that were internationally co-authored, 2003 and 2016, countries producing more than 10,000 papers in 2016, by region (science includes some social science)

Europe	2003 %	2016 %	**Anglosphere**	2003 %	2016 %	**Asia**	2003 %	2016 %
Switzerland	54.5	69.2	New Zealand	44.5	58.2	Singapore	35.0	62.8
Belgium	49.0	66.1	United Kingdom	36.9	57.1	Pakistan	28.2	49.3
Austria	46.3	64.8	Australia	36.9	54.9	Thailand	48.7	40.7
Sweden	45.7	64.3	Canada	39.0	53.0	Malaysia	36.6	38.4
Denmark	47.7	63.3	United States	23.3	37.1	Taiwan	17.5	29.8
Netherlands	44.7	61.8	**Latin America**	2003	2016	Japan	18.9	27.9
Norway	45.6	61.4		%	%	South Korea	25.1	27.0
Ireland	46.1	60.9	Chile	52.7	61.7	Mainland China	15.3	20.3
Finland	41.2	60.4	Argentina	39.2	45.3	India	18.1	17.4
France	39.6	54.8	Mexico	39.6	42.3	**Sub-Saharan**	2003	2016
Portugal	45.0	54.2	Brazil	27.2	32.5	**Africa**	%	%
Greece	35.5	52.3	**Middle East &**	2003	2016	South Africa	40.0	52.1
Germany	39.4	51.0	**North Africa**	%	%			
Spain	33.2	50.7	Saudi Arabia	34.5	76.8			
Italy	33.1	47.3	Egypt	32.7	51.7			
Czech Republic	35.8	41.9	Israel	39.9	50.7			
Poland	29.9	31.3	Turkey	16.3	22.2			
Russia	26.9	25.1	Iran	24.2	20.8			

SOURCE: BASED ON DATA FROM NSF (2018, TABLE A5-42)

National and WCU collaboration data. Table 2.7 shows relatively low rates of co-authorship in China, the United States, Russia, India and Brazil. 'Countries with large populations or communities of researchers may have high rates of domestic coauthorship because of the large pool of potential domestic coauthors in their field. Researchers in smaller countries have a lower chance of finding a potential partner within national borders, so collaborators are more likely beyond their national borders'. In addition, 'the EU programme Horizon 2020 (like its predecessor, the 7th Framework Programme for Research and Technological Development) actively promotes and funds international collaboration within the EU' (NSB, 2018, p. 122). Many projects require at least three EU member countries as a condition of funding. Cross-border publishing is high in Singapore and smaller high quality European research systems like Switzerland, Netherlands, Belgium and the Nordic countries, followed by the Anglophone zone, aside from the US, and most other European countries. Co-publication is lower in East Asia. Saudi Arabian universities (76.8 per cent) employ large numbers of foreign faculty on a part-time basis, boosting their global ranking position.

Examining trends in the twenty WCUs with the highest level of total research output, in the six years from 2009, all of these universities experienced a substantial increase in the number and proportion of papers with international co-authors, averaging at nine per cent. The rate of increase was slower in China, Korea and Japan than Europe, the English-speaking countries and at the University of Sao Paulo in Brazil (Leiden University, 2018).

3.4 *Patterns within the Network*

Networks are flat but are not always symmetrical. Some nodes are bigger than others, and some partnerships are worked more intensely. Lines of influence may be mutual or one way. The United States is the 'largest contributor of partners' (Wagner et al., 2015, p. 7): US-based authors appeared in 38.6 per cent of all co-published articles in 2016 (NSB, 2018, table A5-42). They are directly linked to most countries and indirectly linked to all countries in the global network (Wagner et al., 2015, p. 7). However, in a network setting US leadership is necessarily dominant rather than hegemonic. It is not exercised in zero-sum fashion by excluding other players from entering the network or accumulating connections.

Favoured partners. Within the thickening connections of every nation with other nations, and each WCU with others, some relationships are especially strong because of cultural similarity, historic links, and/or policy and funding drivers. Collaboration index data compare collaboration between the named countries in the pair, relative to the rate of collaboration by both countries with all others. A collaboration index of 1.00 indicates that joint publication is at the level expected on the basis of the two countries' overall patterns; 0.50 indicates weak collaboration intensity and 2.00 indicates unusually strong intensity. The collaborative index is the same for both partners.

Among English-speaking countries, the intense collaboration between Australia and New Zealand (3.38, 1977 joint papers in 2016) reflects the fact they are geographic and cultural neighbours, like Canada and the US (1.13, 19,704 papers in 2016, 43.5 per cent of all joint papers of Canadian authors). Canada was the only Anglophone nation with which US researchers collaborated above 1.00. The US collaboration index with the UK was just 0.77, albeit representing 25,858 papers and 29.5 per cent of joint UK work, because both countries were more intensively engaged elsewhere. Australian co-publication with the UK (8838 in

2016) was less than with the US (12,127) but the UK-Australia index was higher at 1.19 than the US-Australia index of 0.75 (NSB, 2018, tables A5-43 and A5-44).

There is intense collaboration between the three Spanish-speaking Latin American nations with the strongest science systems – Argentina, Chile and Mexico – and between Argentina and its Portuguese-speaking neighbour Brazil. There is another intensive regional collaboration, on a larger scale, between Denmark, Finland, Norway and Sweden. They share geographical location, historic ties and common social systems, and university cooperation in the Association of Nordic University Rectors Conferences (NordForsk, 2018). The six pairings between the four nations had collaborative indexes of 3.16–4.54. There were 9865 collaborative papers across the region in 2016. Nevertheless this was only about 60 per cent of the volume that Nordic researchers co-published with US researchers and 70 per cent of the volume of their joint work with UK researchers. The largest research countries dominate networking activity in absolute terms, even while other connections are more intense.

Table 2.8 shows that both the US and China have only a small number of pairings with above average intensity. US science was intensely focused on neighbours Canada and Mexico, a special tie with Israel (1.33, 4533 papers), and relations with South Korea and Taiwan where the US has played a major role in doctoral training (often the source of co-publication) since the 1950s. In 2016 the US shared 47.6 per cent of all internationally co-published papers involving authors from South Korea, 32.7 per cent in relation to Japan, 32.0 per cent in India, 29.8 per cent in Netherlands, 28.5 per cent in Germany and 25.3 per cent in France (NSB 2018, tables A5-43 and A5-44). Researchers in China had a close relationship with Singapore (2.03, 4413 papers), though intensity has diminished since 2006 (3.02). There was also relatively intensive collaboration with Taiwan and a growing link to regional neighbour Pakistan. The index of collaboration with researchers in Japan declined from 1.51 in 2006 to 1.09 in 2016: the number of Japan-China collaborative papers had multiplied by more than 2.5 but amid the overall growth of research in China the relative importance of collaboration with Japanese researchers has declined sharply. China also sustained intensive links with Australia (9246 papers in 2016) and the US.

The US-China index of 1.19 in 2016 represented 43,968 joint Sino-American papers in 2016, compared to 5406 papers in 2006. This is an immense volume of collaborative science, much the largest nation-to-nation linkage in the world. In total 22.9 per cent of all US co-publishing in 2016 was with researchers from China, and 46.1 per cent of all China's international co-publishing was with researchers from the US (NSB, 2018, tables 5-26, A5-43, A5-44). The collaboration intensified between 2006 and 2016. *This might suggest that the primary China-US relationship in science is collaborative, not competitive.*

Table 2.8 also shows that European science systems like the UK placed each other on high priority, and this may have precluded more intensive relations elsewhere. The UK had indexes above 1.00 for all European countries in the NSB data except the Czech Republic and Russia, but only one intensive relationship

TABLE 2.8 Intensive research collaborations by United States, China and United Kingdom, with rest of the world, in 2016: Rate of international co-authorship in science[a] and engineering papers between named pairs, relative to their rate of international co-authorship with all countries[b]

United States and…		Mainland China and…		United Kingdom and…	
Israel	1.33	Singapore (-)	2.03	Ireland	2.16
South Korea	1.23	Taiwan	1.73	Greece	1.74
Mainland China (+)	1.19	Pakistan (+)	1.23	Netherlands	1.50
Canada	1.13	United States (+)	1.19	Denmark	1.43
Taiwan (-)	1.05	Australia	1.15	Hungary (+)	1.43
Mexico	1.04	Japan (-)	1.09	Norway	1.40
				Finland	1.28
				Hungary (+)	1.50
				Turkey (+)	1.26
				Czech Republic (+)	1.18
				Switzerland	1.21
				Ireland (+)	1.11
				Poland (+)	1.11
				Egypt (+)	1.08
				Russia (+)	1.07
				Austria (+)	1.03
				France	1.01
				Outside Europe	
				New Zealand	1.35
				South Africa	1.33
				Australia	1.19
				Chile	1.01

a. Science includes some social science.

b. 1.00 = expected rate of collaboration, 2.00 = intensive relationship within the global network.

(+) indicates significant increase in rate of collaboration since 2006.

(-) indicates significant decrease in rate of collaboration since 2006.

SOURCE: DATA FROM NSB (2018, TABLE A5-43)

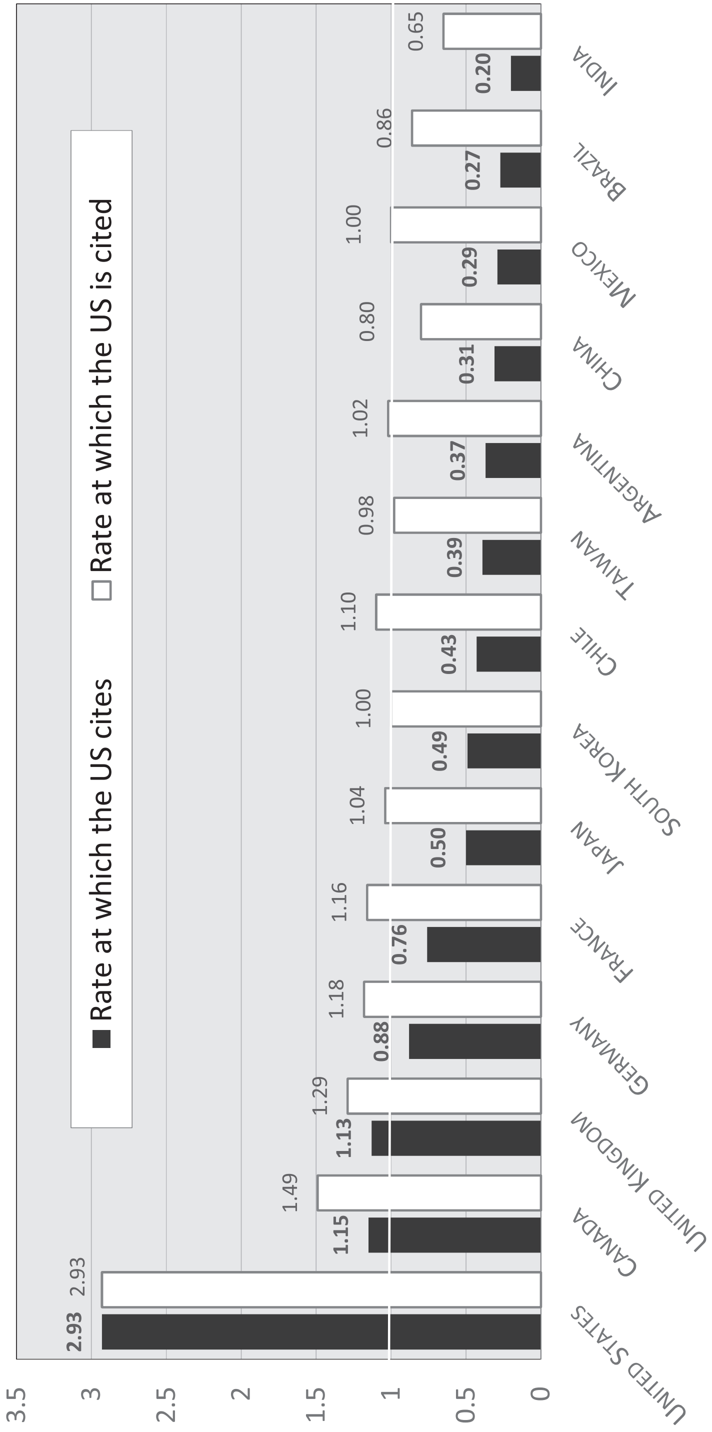

FIGURE 2.7 The rate at which papers by authors from selected countries are cited by papers with authors from United States, compared to the rate that these countries cite United States authors, science and engineering papers, 2014

outside Europe and the Anglophone zone, 1222 papers with Chile in 2016 (1.01). The NSB data show that Germany had collaborative indexes above 1.00 in 2016 for every European country in the data and in most cases the intensity had increased since 2016 (NSB, 2018, tables A5-43 and A5-44). Other European countries have similar European-centred collaboration patterns.

Who cites whom. Another way of mapping cross-border relationships is via data on international citations. As with the co-publication data, the 'expected' or world average position is 1.00 and 2.00 indicates very intensive citation. Unlike co-publication data, the citation data are not necessarily identical for both parties – researchers from country A may cite research from country B more often than vice versa. This contrast enables the mapping of the apparent direction of intellectual influence. Figure 2.7 shows that in every nation US researchers are cited by researchers from that other nation more than US researchers cite them. Americans have a large and strong domestic science system and cite each other intensively (2.93). There is no system of equivalent size in other nations, except in China. Notably, Americans cite research in China at the low rate of 0.37, whereas researchers in China cite US researchers at 0.80. This suggests that Americans influence Chinese researchers more than vice versa. The relationship is collaborative but not yet based on parity of esteem. Whether this is due to different levels of quality, or different levels of cultural closure, or both, cannot be judged from the data. Researchers in only two countries are cited by US researchers at a rate above 1.00, Canada and the United Kingdom. UK researchers come closest to parity of esteem, citing US researchers at 1.29 and being cited at 1.13 (NSB, 2018, table 5–28).

4 Conclusion

Global and international relations have mixed benefits in finance and trade, where there are both winners and losers. However, in higher education and research, cross-border activity can be configured to benefit all parties, provided that relations are conducted on the basis of equality of respect. Brain drain, and the tendency to marginalize non-English language knowledge, are serious problems that have not been adequately addressed.

Looking through a solely national lens, the cross-border activity of WCUs may seem marginal, or an instrument of national competition. Yet global science, communications and mobility are core activities in WCUs across the world. WCUs have established a networked zone of inquiry on the world scale, supported by and formative of traditions of academic freedom that take in a growing number of countries. Cross-border work is attractive to WCUs. In a global space they operate as global civil society actors with fewer constraints on them than at home. In the open global dimension of action, the 'commonness' of WCUs is more developed and they are less bound by the discipline of competition than states imagine.

This chapter has focused on the actual and potential contributions of World-Class Universities (WCUs) to common goods, especially global common goods. The main empirical focus has been global science, with some attention to global mobility. Research and mobility are key aspects of globalization in WCUs and areas of potential national/global tensions. Nation-states can control people mobility, though this is politically difficult, but they do not have the tools to control global research and information (outside military-related research), because of the public good nature of knowledge. The secular trend is to ever-increasing 'flat' research collaboration, between an ever-increasing number and range of national systems and WCUs. The global science system evolves according its own logic (Wagner et al., 2015). *It is becoming more detached from nation-states*. Hence research collaboration between WCUs has a larger meaning. It feeds the slow historical process whereby different national societies, without ceasing to be diverse, are moving towards a one-world society.

Nevertheless, national/global tensions (Rodrik, 2017) pose challenges for WCUs, for example the barriers to academic people mobility amid migration resistance in the US and UK, and the barriers to the full flow of global information in China. And most WCUs will need to more effectively address local/national political imperatives if those universities are to flourish in future. The challenge is to embed higher education and science in a myriad of differing local domains, and to tick the national political boxes, while continuing to move forward with the development of a common global agenda.

Notes

1 This chapter defines 'World-Class University' or 'WCU' not in relative terms (e.g. ranked in a top 100 or top 500) but in absolute terms. A definition based on, say, the comparative top 500 conceals improvement in the absolute level of institutions, and growth in the number of institutions at a fixed level of quantity or quality of scientific output. One simple absolute indicator of a WCU is 1000 published papers over the previous four years, as measured by Clarivate Analytics or Scopus. In the Leiden University ranking, based on Clarivate data, there were 903 such universities at the end of 2015, based on 2012–2015 output.

2 UNESCO's (2018b) term 'tertiary education' is identical to 'higher education' in only some systems. 'Tertiary education' refers to programme, not institution, and includes all programmes at ISCED Levels 5–8, that is, from two-year equivalent academic diplomas (Level 5) to first degrees at Bachelor level (Level 6), Masters programmes (Level 7) and doctoral programmes (Level 8). In many countries, all Level 5–8 activity is classified 'higher education' but in others the term is confined to Levels 6–8 only, or to activity in designated institutions.

3 We thankfully acknowledge Lili Yang for the development of these translated concepts.

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