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The new geo-politics of higher education

Global cooperation, national competition and social inequality in the World-Class University (WCU) sector

Simon Marginson

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Abstract

The outcomes of higher education are not confined to, or even primarily, the creation of private economic and status benefits for graduates. Institutions of higher education generate many other individual and collective benefits, on both the local/national and the global planes. On the world scale, research-intensive universities (World-Class Universities, WCUs, universities producing at least 1000 science papers in 2012-2015) now operate as a single network, one that is increasingly integrated and also operates as positive sum, with the leading research nations fostering emerging science countries through collaboration. While WCUs 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 WCUs are research itself and the systems of communications and people mobility associated with networked activity. The spread of the multi-disciplinary research university form across the world strengthens the scope for linkages. 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 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. In the majority of countries, scientific publishing is primarily shaped by the global system not national organization. Global science also constitutes a vast joined up zone of free critical inquiry, with larger implications for global civil society, a potential counter to post-truth populism. However, global/national tensions can destablize cross-border activities, less in science than in global people mobility and communications. It is becoming more essential for WCUs to strengthen local relations and contributions, as well as advancing global agendas.

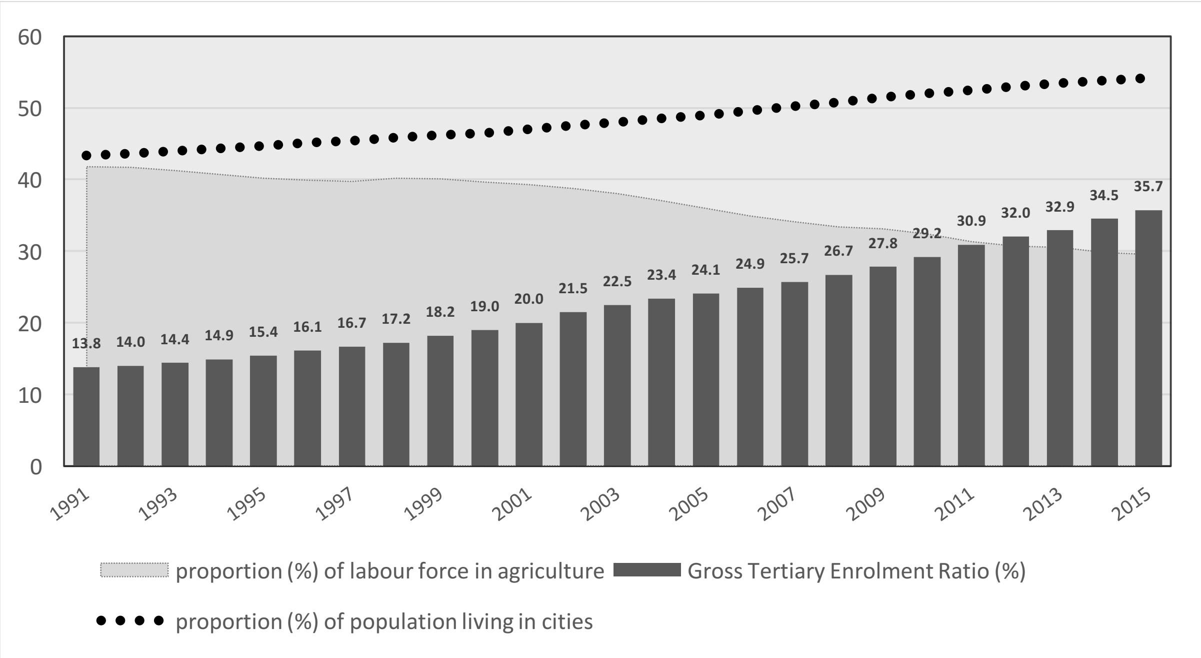
1. Introduction

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 and more engaged kind of higher education that emerged in the United States (US) in the 1950s-1970s—a national system with proliferating, larger 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 engages in cross-border activity —has spread on the planetary scale. In this process, 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 necessarily been controlling. 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 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. Remarkably, the structuring of global higher education still resembles the foundational medieval European universities, with their separated city locations, shared texts and traveling scholars. A principal aspect has been the emergence of a more pluralized set of science nations and research-intensive ('World-Class') universities, [1] facilitated not only by the network growth typical of knowledge-based flows but by the continuing global dispersal of national political-economic capacity in what is becoming the post-imperial era.

Participation. From 1995 to 2015 the world Gross Tertiary Enrolment Ratio (GTER) as measured by the United Nations Educational. Social and Cultural Organisation'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).

Figure 1. Worldwide Gross Tertiary Enrolment Ratio (%), compared to proportion of people living in cities (%) and proportion of labour in agriculture (%), 1991-2015



Source: World Bank (2018), UNESCO (2018a)

The growth of higher education and of science are both 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. In some locations, such as parts of sub-Saharan Africa, market forces propel a patchy modernization by fits and starts. In some other countries, large-scale state investment in infrastructure leads development. In a third group, states, families and market actors seem to move more in tandem, as in East Asia. Conditions for building higher education systems 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 small towns, is being swallowed up by the spread of cities and the manufacturing and service economy. Meanwhile, in countries like the United States that were 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, estimated number of Internet users grew from 16 million to 4157 million, moving from 0.4 per cent inclusion to 54.4 per cent (Internet World Stats, 2018). Even before the peasant community makes the trek to the city, or the city spreads to absorb the village, or the small town's younger people move up the line, all are being drawn into the universal modern imaginaries of consumption, institutionalized work and education.

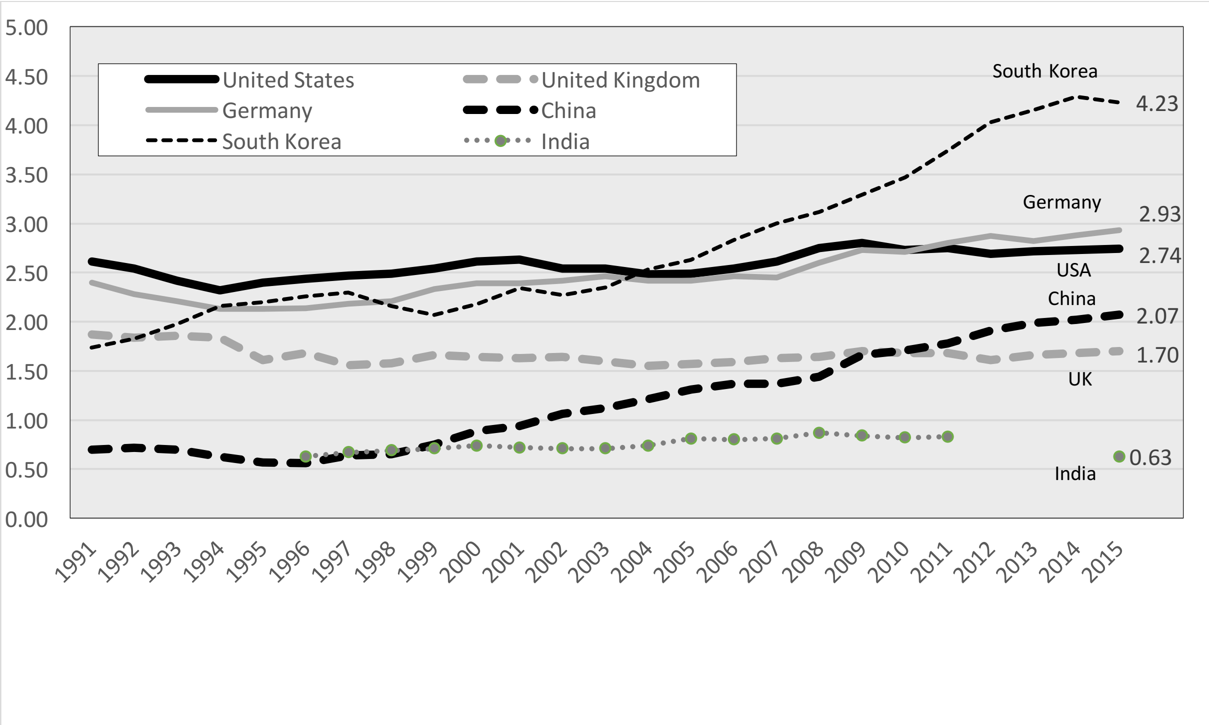
Above all, urbanization, growth in the proportion of the population that lives in cities, especially growth in the urban middle classes, sustains the growth of tertiary enrolments. Between 1970 and 2016 the world urban share rose from 36.5 to 54.3 per cent (World Bank, 2018) (Figure 1). As families move 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 world middle class *doubled in size* between 2000 and 2016. (The middle class is defined as persons with incomes of $10-100 American dollars a day in 2005 purchasing power parity values, $14,600 to $146,000 per year). Kharas finds that ‘within two or three years’ the majority of the world’s inhabitants will be middle class, with the growth of the global middle class concentrated at the lower income end (Kharas, 2017, p. 2), and principally sustained by three of the world’s four most populated nations: China, India and Indonesia (the other is the United States). In China the urban share of population climbed from 17.4 per cent in 1970 to 56.8 per cent in 2016; in Indonesia from 17.1 to 54.5 per cent; and in India from 19.8 to 33.1 per cent. Growth in GTER has followed the upward trajectory of the urban share. 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. Meanwhile, in 2014 in the European Union it was 67.7 per cent and in North America 84.0 per cent, more than four fifths of the school leaver age group (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 qualified persons, in persons as citizens, and in persons with agency freedom. Biesta’s three purposes offer graduates the prospect of Kantian command over time and space: the qualification of persons in diverse and complex knowledges, able to travel through the portals of learned imaginations, the socialization of persons as globally-aware citizens, and agency freedom in the form of mobility: persons at ease in moving across geographical and cultural borders. Whether there will be a concurrent expansion in social opportunities to utilize these freedoms, severally and together, is less apparent (Cantwell, Marginson and Smolentseva, 2018). All the same, higher education's potential contribution to the common good is being enlarged worldwide at a rapid rate.

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 catalyzed by information and communications technologies. With the partial exception of the United States science-based innovations in knowledge, and its applications, are largely sourced not from national science but from the store of global science.

Figure 2. Investment in R&D as a proportion (%) of GDP, United States, United Kingdom, Germany, China, South Korea, India: 1991-2015



There are series breaks for India, with no data for 2012-2014 inclusive.
Source: Author, using data drawn from NSB (2018), Table A4-12.

The dominant role of 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 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 R&D, the GDP proportion devoted to R&D in emerging science systems (the GDP share in mature science systems has increased more slowly), in total R&D investment and in total scientific output. Figure 1 demonstrates the spectacular change in China and South Korea. Between 1991 and 2015 the GDP proportion devoted to research increased from 0.72 to 2.07 per cent in China, and from 1.83 to an extraordinary 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 on research than does Europe/UK and as much as North America (NSB, 2018, Table A4-12). The data are for total R&D, including industry spending. Direct investment in universities varies between 5 and 30 per cent of R&D, depending on country, but part of the industry research is conducted in universities, and universities train a large majority of researchers with PhDs.

Table 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: Author, using data drawn from NSB (2018), Table A4-12.

Between 1990 and 2015 all the science nations in Table 1 more than doubled their research spending in constant dollars. The mature United States research system tripled its spending over the 25 years. China grew its R&D outlay from only $12.8 billion in 1995 to $408.8 billion (32 times larger) 20-years later, moving close to the level of R&D investment in the United States (NSB, 2018). At the same time research across the whole of Northeast Asia and Singapore, the Chinese civilizational zone, also made major advances in science quality, mostly in engineering, the physical sciences and mathematics (see section 4 below). The total world output of science papers, mostly by university researchers and many fed into knowledge-intensive industries, rose from 1.19 million in 2003, to 2.30 million in 2016, growth of 92.5 per cent in 13 years (NSB, 2018). The same period, 2003-2016, 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 are moving to a more central role in social life.

WCUs. 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 continually active as global players. Though their national and global functions are distinct, the evolution of each of national and global capacity provides favourable conditions for the other. Research 'multiversities' (Kerr, 2001) are complex creatures that acquire and combine: national and global, research-oriented and teaching-focused, prestige-struck and revenue-driven, self-serving and society-oriented, selective and participatory, excellent and elephantine. The developmental strategies of many WCUs combine research selectivity and concentration with growing size and weight. Some seem to overhang the societies in which they are embedded, like the cathedrals of an earlier time: lofty and impenetrable, a grace that beckons to many but is given to few. Unchanging, ever-changing, they can be surprisingly nimble, especially when operating abroad. Yet their expansion is significant to more than just themselves. They make a difference to their graduates, to their localities, to their nations and regions, and to the global common good.

The contribution of WCUs to the common good is not fixed but open in historical terms. On one hand, as discussed in section 4, *the common good is inherent in the globalized higher education and knowledge system*. This is a function of modus operandi of open, expanding global networks, to the extent that their core substance is knowledge or information (global public goods in economic terms) rather than economic property or capital. Networked WCUs are naturally disposed to secure mutual positive sum benefits and in a common manner. On the other hand, the contribution of WCUs to the common good is variable from system to system, and subject to social contestation, to state policy and to the missions and strategies of WCUs themselves. The extent to which networked WCUs advance the common good is articulated by two (heterogeneous) factors. The first is the polarity between social inclusion and exclusion in WCUs, which exclusion mostly wins. WCUs are prizes for capture by affluent families that invest in higher education as a private good, especially in very stratified systems. The second factor is the distinction between national and global action where, for much of the time, the global practices of WCUs escape national constraints (more so in relation to research and information flows than in relation to people mobility). Arguably, the contributions of WCUs to global knowledge and free movement are both less ambiguous and more clearly beneficial than their role in social reproduction on the national and global planes. For the most part—there are exceptions to this judgment—WCUs seem to do better in fostering geographical-spatial, cultural and political forms of mobility than they do in sustaining or increasing social mobility in unequal societies.

Contents of the paper. This paper is centrally focused 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 less than 10 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 global perspective of the paper differs from most studies of research universities, that examine WCUs through the lens of methodological nationalism (Shahjahan and Kezar, 2013). The paper also differs from global rankings that treat higher education as a vast zero-sum contest for prestige with a handful of winners. It is impossible to understand the growth of networked science in those terms (Wagner, Park and Leydesdorff, 2015). The potential of WCUs is much larger than suggested by the neoliberal model of university as self-serving firm with customers/students and a 'brand value', the proxy for equity price, that is determined by the ranking positon. For example, consider the robust capacity of WCUs to sustain international relations in a world of nation-states. The drive to internationalize cannot be explained in terms of the profit motive: most cross-border activity is subsidized. The social meanings of WCUs derive from their many connections with other social sectors and with each other, the possibilities unlocked by the knowledge they form and disseminate, and their ongoing effects, direct and indirect, in the lives of their students, graduates, professions, corporations, governmental agencies, civil society organizations and others. WCUs also sit in an open information setting with potential collaborations in all directions. While there is competition within the networked global system, systemic relations and benefits are aggregative, not zero-sum. As in economic markets on their best days, but more so than in market transactions, knowledge-based exchanges are routinely cooperative and positive-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. Hence, and again in contrast with other analyses, the paper focuses not just on individual WCUs and their distribution between nations but also on the combined effects of science/WCUs as a collectively networked whole.

Section 2 is primarily conceptual. It reviews concepts of 'public' and 'common' in higher education and research; models the contributions of WCUs to individual benefit, collective benefit and the national and global common good; and identifies the principal common goods associated with the WCUs sector. These include knowledge, which is close to a pure public good in economic terms; and cross-border people mobility, which shares the public good character of knowledge networks up to a point but is subject to congestion effects.

Section 3 focuses on the global radiation of the WCU. For WCUs the goal is not revenue as such. Money is but a means to the real ends, which are (variously) research power, social-institutional status and common goods. Like most organizations, WCUs strive to accumulate and produce more of what they want, using quantity and quality strategies to do so (a few WCUs constrain the quantitative impulse and focus solely on qualitative advantage). To secure the benefits of science networks so as to maximize research power and institutional status, WCUs conform to the evolving forms of those networks, led by the dominant US nodes with first mover advantage, though there is scope for national and local variations.

Section 4 is primarily empirical and the heart of the paper. In the light of an account of how global networks develop, it discusses the growth and pluralization of research science, global cooperation in science output, and gaps and closures in the network. In Section 4 the potential contribution of WCUs to global common goods becomes more material.

Section 5 returns to the two factors that articulate the contribution of WCUs to the common good: the polarity between social inclusion and exclusion, and the relations (and tension) between the national and global dimensions of activity. In some countries the national/global tension disrupts free people mobility, but the national/global tension is less potent in relation to information and research. The two factors intersect: the contribution of WCUs to cross-border people movement, like their domestic role in social reproduction, can augment social inequality, stratification and polarization. Section 6 is a short conclusion.

2. Public and common good(s) in WCUs

This section begins with discussion of terms that are used when observing, measuring, analyzing and describing the public and common benefits of higher education. It then considers the different global common goods produced by World-Class Universities (WCUs), in the context of the larger set of individualized and collective contributions that they make.

Public good(s) in higher education

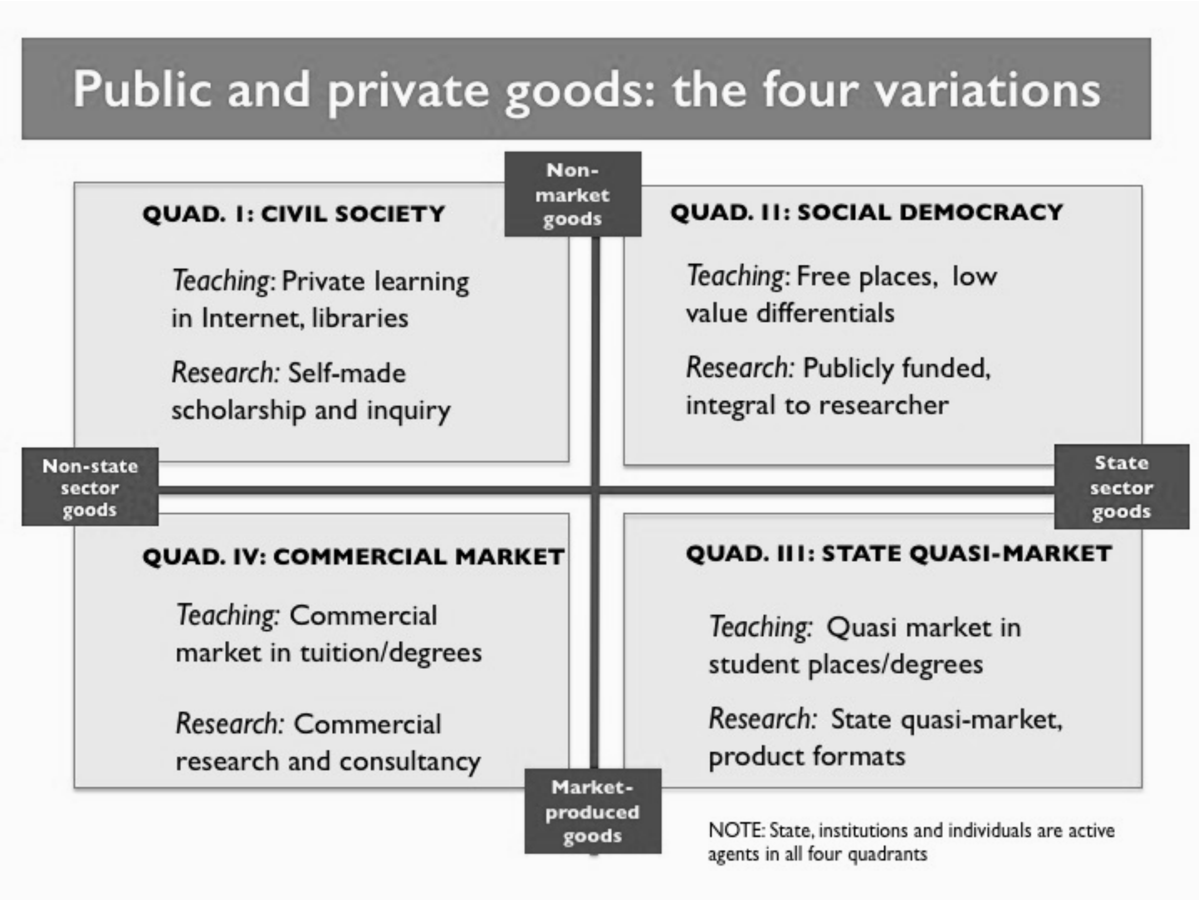
Public good (singular). The term ‘public good’ normally refers to the broadly distributed general welfare or condition of virtue of the public, meaning society as a whole. Rarely well-defined, ‘public good’ can be highly normative. It is sometimes equated with the European feudal metaphor of the ‘commons’, 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). There the idea of public good converges with ‘common good’ (see below). Public good is also associated with notions of democratic and often communitarian forms, openness, transparency and popular sovereignty. In this chapter, however, the term public good (singular) simply refers to aggregated public goods (plural).

Public goods (plural). This term is used more precisely than the singular public good, but has two different meanings that only partly overlap: the political definition and the economic definition. In the simpler 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.[3]

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 (e.g. student tuition costs). But it carries with it 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, and while market failure is a natural phenomenon, this does not exhaust the potential public goods. Other public goods are determined by social relations and state policy. Education and health are 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, such as when society deliberately chooses not to provide education on a market basis, on the grounds that this has perverse outcomes (e.g. restricted access and distributional inequalities), and that there are additional public benefits to be gained from a shared, cooperative, universal approach.

Figure 3. Combining the economic and political definitions of public/private goods in higher education: Four Quadrants, four political economies of higher education



Source: Author. For more discussion see Marginson (2016c), Marginson (2018c).

Once the potential for *policy-created* public or private goods is recognized—this does not affect research, a natural public good, but affects the teaching/learning/credentialing of graduates—then Samuelson's reasoning is reversed. Rather than the intrinsic character of higher education (public or private) determining its source of finance, it becomes obvious that 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 the most prestigious institutions and highest income earning degrees, are scarce, subject to fierce social competition, and targeted by affluent families for private investment. The families that can afford those places, and the educational institutions that produce them, are impelled to focus primarily on higher education as private individual goods rather than collective (common or joint) public goods. Public goods are under-financed and subject to market failure. However, in most countries, government financing and regulation extends beyond considerations of market failure. Populations expect governments to treat student places as non-market goods, for political reasons, to expand equity and citizen rights.

As soon as policy moves away from the minimalist naturalistic approach to public goods Samuelson's zero-sum idea of public/private goods collapses. The rationale for a zero-sum public/private split of financing collapses along with it, except for the need to compensate for market failure. 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.

Hence there are two contrary ideas of the public/private boundary, based respectively on the state/non-state divide, and the non-market/market divide. There is a zone of overlap between the two definitions, in classical pre-capitalist or post-capitalist state activity where the goods are both non-market in mode of production and distribution, and also produced in state sector or state-controlled institutions (Quadrant 2 in Figure 3). It is true that in higher education and research most public goods in the economic sense—goods necessarily produced outside markets, such as non-commercial research—are supported by state financing. However, the overlap between the two different definitions of public/private is by no means perfect. There are substantial areas that do not overlap (see Quadrants 1 and 3 in Figure 3). Seeing the two definitions as essentially the same, and the world split between market and state (just Quadrants 2 and 4), would be highly misleading. First, some non-market goods are supported by private philanthropy, civil and community organization or household activity not the state. They are in Quadrant 1 rather than Quadrant 2. There are many activities in society that are neither state controlled nor market-driven, including much learning and investigative scholarship. Second, states become involved in markets as well as non-market production. They are active in Quadrant 3 as well as Quadrant 2.

Rather than pushing the two definitions together, creating an ambiguous idea of public goods based on the market/state dichotomy, it is more useful to retain the two different and clear-cut definitions of public/private goods. Both the political and the economic definitions of public goods are useful to a point, each has its limits, and neither is sufficient. The political definition acknowledges the scope of governments and politics to make higher education public if that is desired, but is arbitrary, and unlimited in relation to costs. The economic definition draws attention to market failure and defines the minimum necessary level of funding by government or philanthropy to avoid market failure (e.g. in higher education, to finance curiosity-driven research or guarantee universal student access to post-school institutions) but it cannot cope with policy-determined public goods, and cannot comprehend a positive relationship between public and private goods. In sum, neither the political nor the economic definition is sufficient but each is partly explanatory.

Figure 3 shows that when the two definitions of public/private are combined in a matrix, all production in higher education fall in one of four differing quadrants (Marginson, 2018c). This explanatory device establishes a broad potential for public goods of the two different kinds, political and economic, though only Quadrant 2 goods are 'public' in both respects. The heuristic can be used to map production in existing higher education systems, and explore the way that the four differing political economies shape differences in the contents of the products of education and research, and their control and distribution. Most national systems and WCUs have activity in all four quadrants. The balance varies.

Common good(s)

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. In this chapter it takes a more precise meaning, as the combination of all common goods (plural).

Common goods (plural). The term 'public goods' does not necessarily mean goods that are beneficial for all, or even for any one person. Not all public goods augment the general welfare. For example, when a nation conducts an aggressive war against a neighbouring nation, its military effort is technically a public good in both economic and political senses. Yet its actions may not be good for people, in either nation. Common goods are broadly beneficial because they contribute to human agency in the context of sociability. Common goods contribute to shared social welfare and relations of solidarity, inclusion, tolerance, universal freedoms, equality, human rights, individual capability on a democratic basis (Sen, 2000). Equality of opportunity in education is one example. In the Chinese lexicon, common goods are social goods that contribute to the broad humanity (人, Ren). Nordic countries, in which equal and solidaristic society is an end in itself, emphasize policies designed to secure common goods (Valimaa and Muhonen, 2018). Another example is the British National Health Service, which provides universal care free of charge to all, and deploys scarce resources so as to prioritize people in greatest need because of serious illness or accident.

Common goods are collective public goods in the economic sense, being non-market in character, but not always public goods in the political sense. Common goods are produced in both Quadrant 1 (non-state production) and Quadrant 2 (state controlled production) in Figure 3. Epistemologically, 'public' and 'common' have differing statuses. First, as noted, 'public goods' is a technical term for non-market goods, or alternately state determined goods, not a normative term. The term 'common goods' has a necessary normative element. Second, and related to this, while many public goods are open to precise observation, regardless of viewpoint, this is less true of common goods. It may sound strange to argue that a distinction like public/private, which has become so distorted by various ideological claims, can be understood objectively, but both kinds of public good—government produced or controlled goods, and goods produced without competition, prices or the other market relations—look the same regardless of ideology. (Note however that there are ambiguous goods in Quadrant 3 in Figure 3, with some market characteristics but not others, such as state-subsidized non-profit private education). In contrast, because 'common' is normative it is open to both interpretation and historical-political variation.

To take an example, consider policy on segregation in the Southern states of the US after the Civil War, the Reconstruction years. Some newly freed Afro-American families wanted common schools with white families. This happened in a few localities. Other Afro-Americans wanted their own schools, to control their children's education free of racism, and most Southern whites did not want their children to go to school with Afro-Americans: each group supported segregation but for different reasons. Both segregation and desegregation were social-relational common goods in the Reconstruction era, at different times, in different localities, for different people and for different reasons (Foner, 2015). Because 'common goods' are normative any use of the term requires further explanation.

UNESCO argues that education should be understood as a common good. For Locatelli (2018), for UNESCO, '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' is 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). Partial state funding and regulation may be needed to ensure normative commonality (p. 13).

The public sphere. In Kantian tradition which helped to shape the German university, the 'public' domain 'denotes a particular quality of human interaction which is different from that of the private domain and the market domain' (Locatelli, 2018, p. 8), as a zone of self-formation and collective freedom in which the freedom of each is contingent upon the freedoms of all others (Locatelli, 2018; Marginson, 2018a). Education is 'an essential component in the promotion of those forms of human action "through which freedom can appear"' (Locatelli, 2018, p. 9; citing Biesta, 2012). Habermas (1989) identifies a 'public sphere' operating on the boundary between the state and civil society. His example is late seventeenth century London with its network of salons, coffee houses and broadsheets, position at the outside edge of the state, that together constituted public opinion and provided a critical reflexivity for the nation-state in matters of the day. For Calhoun (1992) universities operate in analogous fashion as semi-independent adjuncts of government, providing constructive criticism and strategic options, and expert information that helps state and public to reach considered opinions. Pusser (2006) models the university as a zone of reasoned argument and contending values, noting that US higher education has been a medium for successive political-socio-cultural transformations, such as the 1960s civil rights movement. These notions of 'public' as a zone of critical policy-related discussion adjoining the state have resonance in China, where leading national universities perform the Habermasian role in criticism and innovation, though positioned on the inside edge of the party-state rather than just outside it in civil society (Yang, 2009; Zha, 2011). Peking University was the starting point for most twentieth century political movements in China (Hayhoe and Zha, 2011). Because of their advanced capacity to form self-altering agents and engender critical intellectual reflexivities (Castoriadis, 1987, p. 372); and the way they facilitate mobility across all kinds of boundaries; at times, in many countries, universities have incubated advanced participatory democratic forms. This suggests that one test of a university's commitment to the common good is the extent to which it provides space for criticism, challenge, controversy and new kinds of open political community.

Global public and common good(s)

'Global' as used in this paper 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 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).

The UNDP focuses especially on knowledge as a global public good and argues for open science, a position adopted also, with caveats concerning intellectual property, by the Organization for Economic Cooperation and Development. 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 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. Strictly, because there is no global state, only the economic definition of public goods is relevant. That can be used to consider pays for cross-border goods, or downstream 'global public bads' (negative externalities), when nations affect the welfare of each other (Kaul, et al., 2003). However, international agencies such the United Nations, OECD and World Bank, operating as quasi global state organizations, attempt to shape values-based notions of the collective global interest.

While global public goods are the form of public goods most neglected in policy, the concept has entered higher education policy discourse in Singapore, South Korea and the United States (Sharma, 2011), and from time to time is referenced in the websites of WCUs.

Global common good (singular). By global common good is meant the combined well-being and freedoms of humanity (人, Ren in Chinese); that is, of human society and nations in the world as a whole. In Chinese language 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).

Global common goods (plural). The term global common goods, plural, refers to benefits that arise from higher education and research through cross-border relations, and at the level of the world as a whole, that are broadly accessible to the different countries and people; such as, say, knowledge of chemistry, or the safety and security of mobile students. Global common goods are a sub-set of non-market economic public goods, that arise in cross-border relations—in higher education, in cross-border research and education and in the combined global systems that make cross-border activity possible. As discussed in relation to common goods above, global common goods are more than simply 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. In a world in which networked inclusion continually expands (Castells 2000), joining once separated localities together, people are more engaged with others. There is expanding potential for common goods in global civil society. Global commercial networks (Quadrant 4), such as Google, facilitate the evolution of collaborative common goods in Quadrant 1.

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 global common goods. For UNESCO education is not just a common good but a global common good (Locatelli, 2018). The worldwide system of publicly accessible scientific knowledge is an important global common good, 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 also global common goods.

However, a complicating factor in relation to both global public goods and global common goods is that these rarely reflect a *generic* global perspective. They mostly embody one or another national or regional perspective on 'public' or 'common', such as the Anglo-American models of the WCU embodied in global university ranking. In *Objectivity and Position* (1992), Amartya Sen suggests that an 'objective inquiry' can be achieved by developing a 'transpositional' view, enabling 'position-independent generalizations'. Necessarily, however, this starts from the national cases. 'Any attempt at non-positional objectivity has to start with knowledge based on positional observations' (p. 1, p. 3). However, he states, 'positional specifications tend to be typically incomplete' (p. 5). There is something to be gained by integrating different positions via 'discriminating aggregation' to reach 'a combined view' (pp. 4-5). Hence, transpositional objectivity is not a 'view from nowhere', but a composite of primary information derived in several positional views (pp. 1-2). There are different ways of doing this, including negotiation between different positions, and the 'impartial spectator' who is in some measure sympathetic to all.

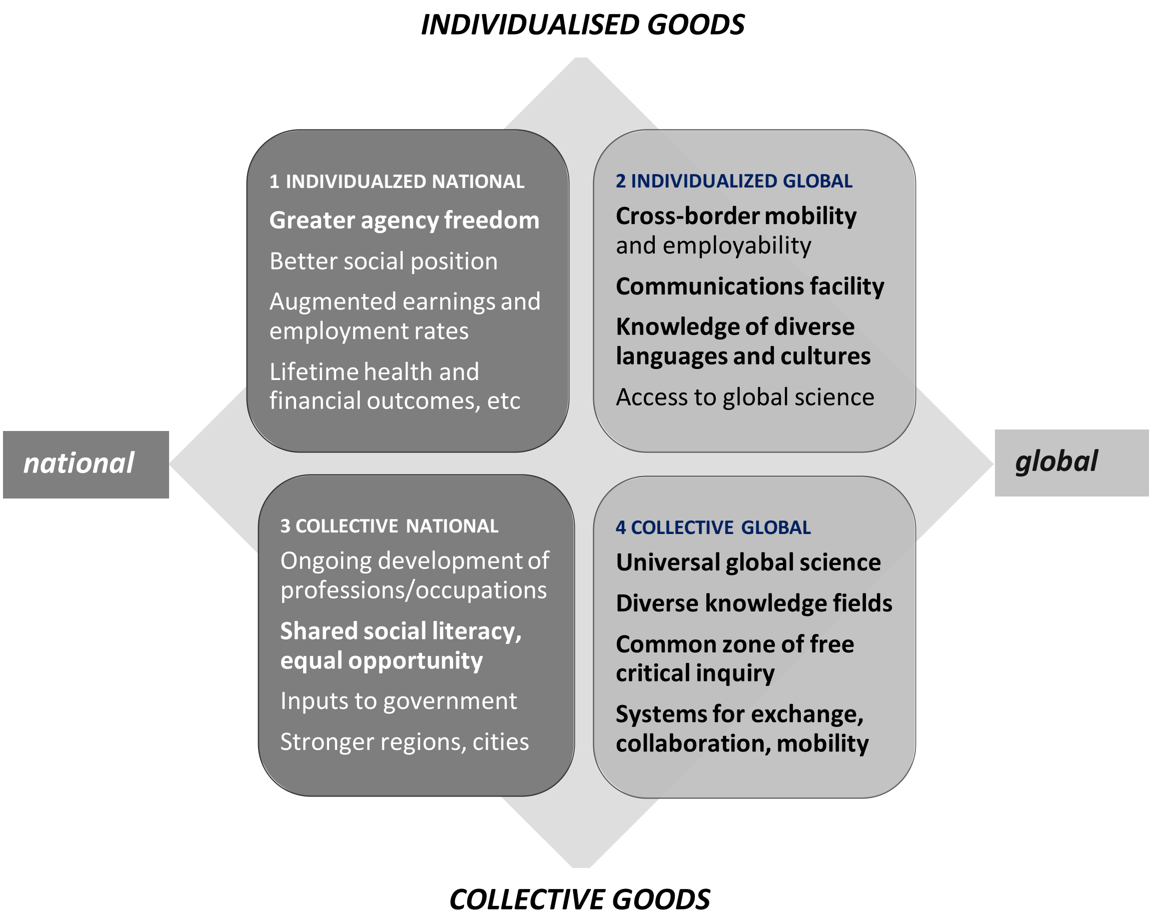
Common goods in higher education

What specific common goods, then, are produced in research-intensive universities?

Individual and collective benefits. Figure 4 is a method of comprehending all of the contributions of higher education—a simplified map of the individualized and collective contributions of WCUs, in the national and global dimensions. WCUs also operate in the local dimension (Marginson and Rhoades, 2002), here seen as a sub-set of the national. In all four categories in Figure 4 there are potential common goods (in **bold type**), meaning relational goods that contribute to shared social welfare and solidarity, inclusion, tolerance, universal freedoms, equality, human rights, and the fostering of capability. Higher education is jointly consumed/produced and conditioned by social settings. It contributes to relational society in many ways. Only some of the individual and collective common goods are listed. For example, under national goods Figure 4 mentions the individual good of greater agency freedom, and the collective goods of shared social literacy and equal opportunity; but the higher education experience also tends to strengthen inter-cultural relations, foster tolerance of difference, augment political participation, and so on (McMahon, 2009).

The global collective benefits of higher education in Cell 3, generated in common across borders, include the knowledge system, disciplinary cultures, communications, mobility and cross-cultural exchange. Research collaboration on common global challenges lifts WCUs above their functions as engines of national and individual advantage and prestige. 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. The common good is not always uppermost. Nevertheless, the expansion of worldwide research networks means that the potential global commons is also expanded.

Figure 4. Examples of individualised and collective contributions of higher education (common goods in **bold** type)



Source: Author

In discussion of the outcomes or benefits of higher education, the focus tends to fall on Cell 1, the individualized national goods, especially the private market value of graduates as 'human capital', conventionally measured in terms of graduate employment rates, and rates of return associated with degree-holding and based on lifetime earnings. The cross-border individualized benefits (Cell 2) tend to be 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 well understood. It is true that higher education is a process of personal self-formation (Marginson, 2018a) that augments individual capabilities and opportunities. This includes career and financial benefits, and also a much larger number of individualized effects, as Biesta's (2009) trio of qualification, socialisation and subjectification suggests. However, there is also much more to higher education than its direct effects in relation to students/graduates. Direct effects on graduates indirectly effect those with whom those graduates live and work, and flow into the institutions, systems and languages of complex societies. Because higher education forms people in terms of social relations and on a large scale, it is both formative of society and continually formed by society. People emerge and develop on a relational basis (Vygotsky, 1978)—in fact each of individual and society do not exist without the other (Dewey, 1927). In *social* science it is absurd to model higher education as if it produces only autarkic individuals. Yet this is what is suggested by policy economics, when it confines the focus to individual benefits.

Here the normative dimension of common goods in higher education becomes material social practice. If students, graduates and their families are told by political leaders and public media that the main (if not the sole) purpose of higher education is to produce benefits for them as individuals, in the form of jobs, earnings and superior social status, then all else being equal, those graduates will be less community minded—less committed to the common good—than they would be if told that their higher education should and does benefit the whole society. Further, if the main if not sole purpose of higher education is the production of individualized private benefits for students/graduates, then non graduates and families outside higher education have no stake in it. A narrow individualized definition of the contributions of higher education opens up it to the populist challenge. If the purpose is seen as simply to produce would-be elites, and that is how the success of higher education institutions are judged, then all of those institutions, especially WCUs, are rightly charged with elitism. On the other hand, if the mission is seen as public in the political sense, and higher education is seen as the producer of a broad range of common goods—including graduates normally expected make a rational contribution 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. If WCUs are seen as a public and common resource, common goods are more likely to result.

Global common goods in higher education. WCUs produce three kinds of global common goods. First, they help many students and faculty and other staff to form global relational competences—knowledge, skills and sensibilities that enable people to relate and 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 the executive leaders of universities. Third, as 'thickly' networked institutions they constitute a space for common conversations of two kinds: the many specific conversations in the academic disciplines, and also generic conversation on matters of the day, as in the Habermasian public sphere. In of all these ways—the effects in relation to individual agency, the facilitation of physical people mobility, and the maintenance of networked conversations—WCUs are more globalized than the national societies in which they sit.

In the global dimension, win-win cooperation in science and WCUs has been greatly facilitated by global communications. In networked relations, in which new agents freely join the network at negligible cost, each existing node gains from the successive addition of new nodes which multiplies the potential linkages. In higher education and research this means the multiplication of potential new ideas, collaborations and synergies. Cross-border people mobility in higher education, and WCUs' intrinsic contributions to international engagement, tolerance and understanding, all augment the potential for collaboration.

Global attributes of individuals. Learning and work in higher education are associated with enhanced individual capacity to travel, in two respects: capability in information and communications technologies (ICT), cross-border electronic sociability, the capacity to travel electronically across the earth; and capability in physical travel. 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 ways.

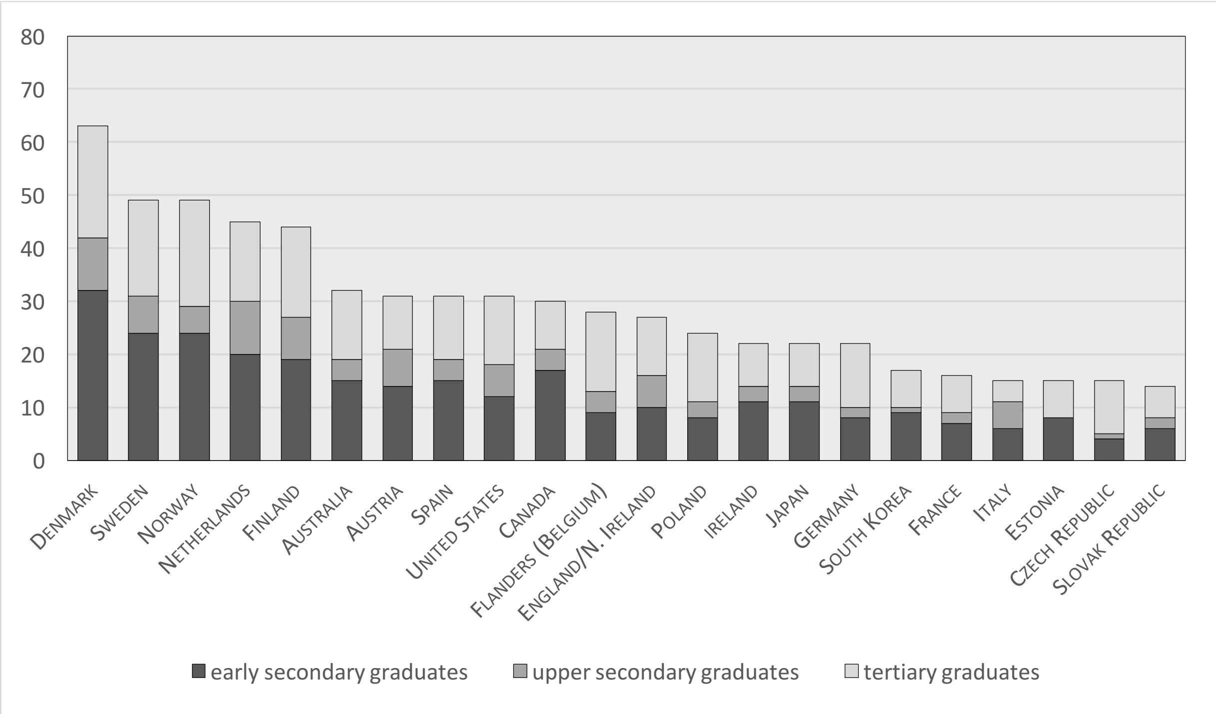
The 2012 OECD Survey of Adult Skills includes data on the incidence of ICT-related skills according to educational qualification. Of the 25-64-year olds with tertiary qualifications, 52 per cent had 'good ICT and problem-solving skills'. Only 7 per cent had 'no computer experience' or refused an ICT 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, 7 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, while only some students and faculty physically move across borders while in higher education, the average graduate is more at ease than is the non-graduate, with travel in this form. 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 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. Mobility 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 (in fact some would argue mobility within and across national borders is a human right). Further, in boosting the capacity to be mobile, higher education expands relational society, 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’, by level of qualification. As education level rises people are more likely to trust others (Figure 5). For example, in Denmark, Norway, Sweden and Finland, which have a solidaristic social model, not only is the level of trust relatively high but 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). In most countries the difference in trust between tertiary and upper secondary graduates is especially significant. While the OECD survey did not ask directly about trusting foreigners, these data again suggest that graduates have advanced capabilities in social relations.

Higher education also helps to form other Cell 2 (Figure 4) relational attributes that facilitate global mobility, communication and understanding, like language skills, knowledge of other countries, and cultural tolerance (McMahon, 2009), in both the formal curriculum and the experience of cosmopolitan university settings. 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 and Adams, 2012). Prolonged mobility experiences abroad quicken personal flexibility in the face of difference and change, and heighten confidence, proactivity, awareness of one’s identity, and reflexive self-determining agency (Marginson, 2014). In many if not most countries that have WCUs, cross-border mobility, and internationalization at home, are more prevalent in WCUs than in other higher education institutions. This is a function of the institutional resources of WCUs and the socially elite character of much of their populations, which carry financial and cultural resources that facilitate mobility, and also the extent to which WCUs are globally networked in research and partnerships. WCUs subsidize mobility in both directions. Some also receive government funding for inward and/or outward travel.

Figure 5. Proportion (%) of people answering 'yes' to the question 'Do you trust others?', OECD nations, 2012 OECD Survey of Adult Skills



Source: Prepared by author using data from OECD (2015), p. 163

A few WCUs (e.g. the National University of Singapore), provide half or more of their students with cross-border experience; though outside Europe, where the Erasmus programme systematizes large-scale student mobility, the total incidence of WCU student and faculty mobility is normally much lower than this. With some exceptions and national variations, WCUs also tend to have more cosmopolitan academic faculty populations. In certain leading English-speaking WCUs, half or more of the faculty are foreign born.

Global mobility system. Networked higher education institutions and national higher education administrations form a common informal system that facilitates ease of movement across borders, which includes within it formal frameworks such as Erasmus in Europe. The mobility system in turn enables students and staff to acquire individualized global goods (Cell 2 in Figure 4), 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 (one example is the China Scholarship Council programs); 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). Individual countries including China and the United States collect data on shorter incoming student stays. Many countries track outward student stays. Data on 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.

Table 2. Internationally mobile or foreign doctoral students as a proportion (%) of all doctoral students in 2015, OECD systems, Brazil and Russian Federation, 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.* (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* (12)	8.7
UK (37)	42.9	Canada (20)	24.4	Slovenia (1)	8.5
Belgium (7)	42.3	Brazil* (6)	22.4	Chile (2)	8.4
France (22)	40.1	Portugal (3)	21.2	Hungary (2)	7.2
USA (146)	37.8	Norway (3)	20.5	Turkey* (1)	6.5
Netherlands (12)	36.2	Finland (6)	19.9	Israel* (6)	5.5
Sweden (11)	34.0	Japan (18)	18.2	Russian F.* (2)	4.5
Australia (20)	33.8	Czech R.* (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		

* Indicates foreign citizen students (including long-term residents) and not just internationally mobile students
Source: Author using data from OECD (2017), p. 300; ARWU (2018)

Between 1995 and 2011, the worldwide number of cross-border student increased at a rapid rate from 1.7 to 4.4 million. After 2011 growth slowed and the total was 4.6 million in 2015, though there were also 13 million cross-border online students (OECD, 2017, p. 295). Within national systems WCUs are much the most active providers of opportunities for student mobility. One example is the commercial form of international education in the UK, Australia and New Zealand. This fosters instances of very large cross-border student enrolments, often in WCUs, which draw unit surpluses from high fee international education to part-finance research. The University of Melbourne in Australia, 39th in the ARWU in 2017, in 2014 had 13,200 effective full-time international students—29.1 per cent of total student load—and secured USD $224.5 million in fees from them (DET, 2018). In the UK, University College London enrolled 4470 full-fee non-EU international students in 2016-17, 11.8 per cent of all students (HESA, 2018). In the United States international education in WCUs is less commercial in purpose, and WCUs mostly have lower volumes, but in 2015-16, 13,340 students (8.2 per cent) at the University of Southern California were international (IIE, 2017). China is also becoming a major provider for international students (OECD, 2017), with growth of student numbers in WCUs driven primarily by foreign policy objectives and university internationalization strategies rather than by revenues. For example, China is currently expanding scholarship aid to 'Belt and Road' emerging countries in Asia and Africa.

Table 3. Recipients of United States doctorates on temporary visas, by country of origin, four largest country groups, by science-based discipline, 1995-2015

Disciplinary field	China & 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: Author, using data from NSB (2018), Table 2-15

Rates of mobility are higher in doctoral education (see Table 2) than at earlier stages. International students constitute 4.3 per cent of all first-degree students in OECD countries but 11.5 per cent at Masters level and 25.7 per cent at doctoral level (OECD, 2017, p. 300). Mobility of doctoral students, post-doctoral researchers and later career researchers is vital to, and continually formative of, the global research system. '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 also augment the reputations and revenues of WCUs. In turn rankings articulate the global competition for talent, magnifying the power of attraction of strong systems and WCUs. Talent flows are skewed in favour of the leading countries, though mobile doctoral students play a varying proportional role in those countries—large in the United Kingdom, United States and Netherlands; more modest in Canada and Japan; relatively minor in Germany, Israel and Korea, though all these countries have a robust WCU sector. Switzerland has more international doctoral students than nationals. The STEM disciplines place the largest part in doctoral mobility. In 2015, 28 per cent of mobile doctoral students were working in natural sciences and mathematics; a further group of 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 such population (OECD, 2017, p. 288). US research in STEM is highly dependent on internationally mobile doctoral students, especially from Asia. Table 3, adapted from 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, of whom 68,379 were from China, with 63,576 (93.0 per cent) in STEM fields; and 32,737 from India, 30,251 (92.4 per cent) in STEM. The next largest country sources of STEM doctorates in the United States between 1995 and 2015 were South Korea (20,626) and Taiwan (13,001), then Turkey (6610) and Canada (6350) (NSB, 2018, Tables 2-14 and 2-15).

Table 4. Plans to stay in the United States, Chinese and Indian recipients of US science and engineering doctoral degrees, 2004-07 to 2012-15

	PhD graduates originally from China			**PhD graduates originally from India**		
	2004-07	**2008-11**	**2012-15**	**2004-07**	**2008-11**	**2012-15**
Number of doctoral graduates in US	15,561	16,120	19,078	5774	8936	9113
Planned to stay in US after graduation (%)	91.0	85.6	83.4	89.1	86.6	86.5
Definite plans to stay in US (%)	58.9	54.9	49.4	61.9	57.8	50.9

US = United States
Source: Adapted by author from data in NSB (2018), Table A3-21

Unlike research collaboration, some people mobility is win-lose rather than win-win. Many student source countries experience a net loss of talent, because PhD graduates stay in the countries of education, especially the United States with its large pool of work opportunities—though these graduates often maintain networks in their home countries, and many return or circulate at later career stages. The same National Science Board data set also indicates that a growing proportion of the foreign doctoral students who graduate from United States' universities do not stay in the US after graduation. For example, of American doctoral recipients from China in 2004-07, 91.0 per cent evidenced plans to stay and 58.9 per cent said they had definite plans to stay; but of the 2012-15 group of Chinese students with new doctoral degrees, a lesser 83.4 per cent had plans to stay and 49.4 per cent had definite plans. The stay rate was higher in mathematics and computer science than in other fields. Graduates from India also had a decreasing tendency to stay (Table 4). This was likewise the pattern for graduates from Iran, Turkey, Canada, Germany and Japan, though over the same period the stay rate did not change for graduates from Mexico, and increased for those from Taiwan (NSB, 2018, Table A3-21). If US training of doctoral graduates contributes to the worldwide common good, because it broadens and deepens the world science system, then that common good is becoming more widely dispersed. The declining stay rate both reflects and contributes to the pluralization of scientific capacity.

Networked global research and free inquiry. Perhaps the most important global common good of WCUs is that, as noted, they sustain an expanding worldwide space for research inquiry and other modes of academically codified thought and the dissemination of the results as scholarship. Wagner, Park and Leydesdorff (2015, p. 1) remark that ‘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 and Salmi, 2011); the culture of collaboration in every university, that fosters bottom-up disciplinary exchanges in each sciences and non-science: together they constitute not only a vast joined up machine for intellectual production, but a space for free inquiry on the global scale, a world mind, one that spreads and deepens along with the spread of WCUs. In their study of the growth of global cooperation in research, Wagner and colleagues emphasize that global networks have developed a life that is joined to but also distinct from national science:

> 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, Park and Leydesdorff, 2015, p. 1).

The practices of intellectual inquiry fostered in the globally networked zone between researchers and between WCUs—often a stronger influence than solely national practices, especially in the hard sciences—sustain both positive/effective freedom, meaning freedom to do things, and negative/control freedom, meaning freedom from constraint (Berlin, 1969; Sen, 1985). In collaborating continually within an open setting, WCUs at one and the same time stimulate, enhance and support each other’s practices of research and scholarship. Though nations need to spend money to join with the global science system, collaboration also creates shared benefits and reduces costs on a continuing basis. At the same time, networked linkages strengthen agency freedom (Sen, 1985), the scope for self-determining intellectual action, in every WCU. Violations of academic freedom are visible, repressive national governments are called to account, and multiple cross-border pressures can be brought to bear—though not always successfully—on locations where violations occur.

Section 4 below details the growth in networked research cooperation. While data on collaboration do not distinguish between open-ended relations and more exclusive linkages, separate common good-collaborative behaviours from competitive behaviours in research, or specify the normative content of research programmes, it is clear that collaborative cross-border research has become crucial to meeting common global challenges. As stated by Patrick Aebischer, President of the Ecole Polytechnique Federale 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).

Public rationality in civil society. Networked WCUs also support a larger common conversation; an expanding cross-national space, more deeply rooted in some countries than others, in which the emblematic modes of communication are reasoned argument and evidence-based truth; and (less clearly) there is a shared commitment to liberal virtues of free discussion, reflexive social criticism, balanced modernization, mutual prosperity and poverty alleviation, ecological sustainability, universal education, cosmopolitanism and human rights. This university-orchestrated public culture, which is critically opposed to marketing discourse, fake political news and other forms of 'post-truth', draws definition from global science, Kantian enlightenment and its notion of public rationality (Sujander, Kivela and Sutinen, 2012), and a broadly distributed version of the Humboldtian idea of the university with its notions of university autonomy and academic freedom (Rohstock, 2012). This university-orchestrated public rationality extends well beyond the economic purposes ascribed to higher education and research—human capital, economic growth, innovation in the 'knowledge economy'—and it sits uncomfortably alongside corporate university instrumentalism. Rather it blends into national and global civil society, providing part of their content and reaching beyond faculty and students to take in a larger population of the university-educated and university-touched. This includes the professions, parts of the cultural, political and business elites, and media and the arts. Like WCUs themselves, the university-orchestrated public culture is a social network both culturally exclusive and culturally open, skeptical of power and intermittently democratic, combining club goods (non-rivalrous but exclusive) with Habermas's public sphere. If the origins of the Kantian university are primarily in Europe and North America, this culture has now become more widely dispersed. It transcends the purposes of individual nation-states, and takes in the global agencies: at times and at best it seems to anticipate the evolution of world society.

The extent of WCU-orchestrated public rationality partly depends on the scope for open civil society, distinct from corporate-controlled markets and the machinery of states. Societies and polities vary in the room they give to civil community—wide in the United States or India, more state-influenced in England and Western Europe, harder to define in China. In China there can be more debate about public affairs inside the party-state than outside it. But the potential for public rationality is continually advanced—and importantly, democratized—by the growth of participation at higher education stage and by the social expansion in the weight of scientific research and intellectual scholarship. All of these elements foster individual and communal agency. Hence the massive growth of China's higher education system, and of its stellar science, facilitates liberalization, democratization and the potential for public culture, whether or not China remains a dynastic regime and a singular party-state. At the same time, university-centred and influenced civil cultures are also vulnerable to populist challenge, in which those without higher education, particularly in rural areas and smaller towns outside the global cities, can become ranged against cosmopolitan cultural 'elites'. The Brexit vote and Donald Trump's election in 2016 showed the divide between the university-educated and others, and rejection of science and 'experts', can be mobilized as a source of populist power (Silver, 2016; Swales, 2016).

The President of Central European University, Michael Ignatieff, suggests that the counter-populist potential of WCUs is part of their public virtue. Far from being anti-democratic, it is an essential component of a Lockean polity with its division of powers:

> Academy freedom and university autonomy are under attack these days as the privileges of a professorial elite, but they should be understood as 'counter-majoritarian institutions' – like a free press and an independent judiciary – an essential counter-balance to majority rule. Across Europe, counter-majoritarian institutions are under pressure from populist movements and parties seeking to mobilise 'the people' against the press, the courts – and universities too. (Ignatieff, 2018).

While the Lockean political configuration is less relevant to the unitary states of the Chinese civilizational zone, they, too, have a tradition of autonomous scholars that speak truth to power. Nevertheless, Ignatieff (2018) also notes, if universities' 'anti-majoritarian' function is part of their contribution to the common good they need public support to carry it out. While the expansion of participation in higher education makes it more difficult for the non-educated to be mobilized against the educated, it also makes the leading WCUs harder to enter (see section 5), unless states or WCUs themselves take action to maintain social acccess. Habits of intellectual and social exclusion make WCUs vulnerable to political isolation, unless they remake the compact with the societies in which they are embedded.

3. Spread of the Global Multiversity

Despite the political problems facing WCUs in some countries, the form of institution that is embodied in the large multi-disciplinary research-intensive university continues to spread.

In the research literature on diversity in higher education, it is often assumed that the growth of enrolment and provision must trigger a greater variety of institutions by type. It is assumed that more diverse student populations will seek more diverse offerings, and institutions (and states) will provide them. A counter-strand in the research, which has better empirical corroboration, finds that the nature of production and the missions of the different higher education institutions are determined more on the supply-side than the demand-side. The bulk of empirical studies of diversity find that both market competition and state regulation carry tendencies to homogenization, unless states deliberately factor in diversity, for example a binary structure in which two groups of institutions have contrasting missions (for a summary of the literature and discussion see Antonowicz, et al., 2018). Institutional theory confirms the second line of argument, noting tendencies to isomorphic imitation and convergence in all modern organizations (Drori, Meyer and Hwang, 2006).

System shapes. System structures in higher education are inherited from history, while also subject to variable policy and regulation, and in some countries to market-led evolution. The degree of influence of market forces is likewise policy-determined and variant. This paper does not permit a full survey of tendencies in system design. However, observation of the OECD countries, and major non-OECD systems such as China, India, Brazil and Russia, suggests that the following hypotheses might be tested in future studies:

1. Overall, with some country exceptions, among onsite institutions (i.e. excluding online only provision), diversity by institutional mission or type is static or declining (see Pinheiro, Charles and Jones, 2015; Antonowicz, et al., 2018);
2. Overall, there is a reduction in the role of discipline-specialist institutions, and binary sector institutions other than academic universities, as indicated by decline in their shares of the number of institutions and proportions of the student enrolment. Specialist institutions (e.g. China, Russia, Australia) and binary sector institutions (e.g. UK, Australia, Norway) are merged into comprehensive multi-disciplinary universities, or upgraded to nominal equivalence with academic universities and expected to increase research and doctoral students (a process underway in Ireland);
3. An increasing proportion of research activity is being conducted in comprehensive multi-disciplinary universities rather than in separated state-established research academies or institutes, or is now conducted on a joint university-academy basis;

Table 5. Proportion of all tertiary enrolment that was at Levels 6-8 (bachelor, master, doctoral degrees): world and selected world regions and countries, five-year intervals, 2000-2015

Proportion of enrolment in	2000 %	2005 %	2010 %	2015 %
Developed countries	80.7	82.2	82.3	77.6
Developing countries	78.6	75.2	76.6	80.1
Europe	79.4	84.5	87.1	89.9
North America	78.6	78.6	77.7	63.5
China	52.5	53.0	55.7	57.4
Russia	66.1	78.1	82.2	80.9
Brazil	n.a.	94.3	88.1	99.9
World	78.5	78.0	78.7	79.6
World tertiary enrolment (*millions*)	*99.9*	*139.6*	*181.5*	*214.1*

n.a. = not available
Russia data for 2009 not 2010. Curious fluctuations occur because of changes in data compilation, e.g. between 2012 and 2013 North America decreases from 77.6 to 63.5 per cent, and Brazil increases from 87.0 to 99.5 per cent.
Source: UNESCO (2018a)

4. In many though not all countries, despite the overall growth in the proportion of young people who enter tertiary institutions, a growing proportion of all higher education students are located in designated 'universities', due to name changes in binary second sector and specialists institutions, the folding of some non-universities into universities, and shift in the balance of supply/demand in favour of universities;
5. In addition, it is likely that because in some countries the research mission is spreading to more institutions (in part by absorbing second sectors into academic university sectors), and because research universities are attractive, a growing proportion of all students are in research universities. But this varies by country;
6. The comprehensive multi-disciplinary research university, led by the globally recognized WCU, enjoys unchallenged prestige as an institutional form in higher education, and has enlarged its hegemony compared to other kinds of institution. Only a handful of specialist and smaller scale elite institutions (e.g. liberal arts colleges), some using the title 'university', sustain equivalent prestige;
7. The average size of comprehensive multi-disciplinary universities, including WCUs, grows continually. For elite research universities, size is one source of advantage;
8. Although the number of students enrolled in WCUs is growing, their proportion of the total enrolment is not. WCUs are becoming more selective. There is probably larger total growth in the layer of research universities below genuine WCU level.

Table 2 underlines the consolidation of degree-level tertiary education amid growth. From 2000 to 2015 the world average enrolment at ISCED Levels 6-8 (bachelors, masters and doctorates) hovered just below four students in five, moving up slightly from 78.5 percent of 99.9 million students in 2000 to 79.6 per cent of 214.1 million students in 2015. UNESCO (2018b, p. 48) states that ISCED Level 5 programmes, below degree level, are often 'short-cycle' programmes: typically, 'practically-based, occupationally-specific' and preparing students 'to enter the labour market'. In addition, 'academic tertiary education programmes below the level of a Bachelor's programme or equivalent are also classified as ISCED level 5': these are normally two-year full-time enrolment equivalent. Aside from the upward increase in the proportion of enrolment in North America at ISCED Level 5, which also affects the proportion in the developed countries in Table 5, the clear overall pattern is a shift in provision towards degree level. It is striking that the great growth in total numbers in tertiary education has been accompanied by this upgrading in the average level and duration of study, and outside North America a decline in the role of the often vocationally specific sub-degree programmes. Some will find this counter-intuitive, especially those who see the expansion of higher education as driven by needs for human capital. Tertiary education is being provided at a slightly higher status level, and slightly more in generalist degrees, and distributed much more broadly than before. The shorter vocational training programmes seen as most closely attuned to the needs of industry have lost a little ground.

The global multiversity. The combined effect of the eight tendencies listed above, despite local exceptions, is to centre more activity on comprehensive multi-disciplinary universities. Within this group the comprehensive research university, the multi-purpose 'multiversity' identified by Clark Kerr (2001), may be gaining ground in both quantitative terms (an increasing share of the total tertiary enrolment) and quality (as an institutional form it is more socially dominant). Above the other research universities, the hegemonic WCU, though harder to get into than ever, has been bought closer to the common imagining by the larger spread and partial democratization of the multi-disciplinary form and the title 'university'—for in the popular mind, 'university' is associated especially with the WCUs that are the leaders of the pack. The 'idea of a university' has been universalized, it seems. Momentarily (though only momentarily) every university can imagine itself as Harvard.

In practical terms the WCU profile is normed by global rankings, which are primarily determined by performance, capacity and reputation in research. WCUs fashion their strategies to maximize their ranking (Hazelkorn, 2015). Research rankings are powered by the quantity of research quality; not just the total volume of papers but the numbers of highly cited papers and leading researchers, in two disciplinary clusters: the physical sciences/engineering, and the life sciences/medicine. This creates strong incentives to be fully comprehensive in the sciences and to continually grow high performance areas though linear expansion, institutional merger and talent recruitment. Increasingly, universities across the world adopt the features of the research multiversity first described by Kerr (1963/2001)—large, multiple in function and stakeholders, more diverse inside, more similar to each other on the outside, and with an ever-growing list of agendas, activities and clients.

For most universities, including WCUs, the way forward is expansion and combination (Antonowicz, 2018). The merged of once diverse campuses is facilitated by communications and information systems that enable performance and finance data to be managed across heterogeneous structures and separated sites. These systems also facilitate growth in size and market share. Large multiversities with diverse resources have more options in the face of national and global challenges—and more funding for teaching means more funding for subsidizing research. It is very significant that institutional higher education is developing, everywhere, primarily via growth and combination, *not* via the de-bundled missions, nimble niche specializations and on-line substitutions that are persistently suggested by the market imaginary. The market imaginary is badly wrong about the developmental logic of higher education. This is because the graduate 'product' is not isolated, customizable goods, but a degree that rests on institutional-social status, accumulated over time, that rests on aggregated resources articulated by competitive performance. Hence both expansion strategies (quantity) and research concentration strategies (quality) generate prestige and resources for WCUs. What has changed is that the average point of equilibrium between the quantity strategy and quality strategy is now fixed at a larger level of scale and complexity.

Table 6. Average size (effective full-time student load) of the 23 Australian research universities listed in the 2017 Shanghai Academic Ranking of World Universities, 1988, 2001, and 2005-2015

Category	1988	2001	2005	2010	2015
Average size of leading 8 Australian research universities in:	9811	19,701	25,765	30,981	35,429
Average size of 23 Australian research universities listed in 2017 ARWU in:	8238	18,069	21,688	26,930	31,087

ARWU = Academic Ranking of World Universities. Average of 22 universities in 1988 as University of Western Sydney did not exist. Leading 8 universities are Melbourne, Queensland, Monash, Sydney, Western Australia, Australian National University, Adelaide, New South Wales.
Source: Prepared by the author from data in DET (2018) and earlier equivalents. Data compilation changes affect the comparison between 1988 and later years. University selection at ARWU (2017)

While some elite WCUs deliberately stay small (e.g. Caltech which enrolls just over 2000 students), or are constrained by policy or site limits, many use size and growth to advantage, especially research volume. These include the world's leading research university, Harvard, which produces more than twice as much high citation science as the next strongest research university Stanford (Leiden University, 2018), and the University of Toronto in Canada, which enrolls over 80,000 students and is the world's third largest producer of high citation science. In China, Zhejiang, Tsinghua and Shanghai Jiao Tong Universities, among others, have used growth to build advantage.

Australia provides an example of the growth and consolidation of the multiversity form. It had 23 universities in the 2017 Shanghai Academic Ranking of World Universities (ARWU, 2017), a large number for 24.1 million people (2016). Table 6 shows the average enrolment of these 23 research universities increased from 8238 equivalent full-time students in 1988 to 31,087 in 2015. Among research universities in the 'Group of Eight', all in the ARWU top 150, average size moved from 9811 to 35,429 equivalent full-time students (DET, 2018). Australia is a signal case in another way—while in the mid 1980s, a majority of higher education students, and the vast majority of ISCED 5-8 students, enrolled in non-university institutions, in 2016 over 90 per cent of ISCED 6-8 students were in designated doctoral research universities (DET, 2018). In 2014 just 16.0 per cent of students were at Level 5 (UNESCO, 2018a). In Australia, as in many countries, processes of massification and upgrading, qualitative and quantitative change, seem to have reinforced each other. Amid this development the enlarged research university has become an emblematic modern institutional form, more central to society than the miscellany of types that preceded it.

Another example is the Russian Federation. When institutional consolidation coincided with expanding enrolments in the 1990s and 2000s, the average number of students per institution rose—from 3661 in 1995 to 4913 in 2000, and then to 6615 in 2005. This was despite an increase in the number of private institutions amid marketization reforms. However, in the last decade the number of students per institution has fallen again, due to a major demographic reduction in the pre-tertiary age cohort (Smolentseva, et al., 2018)

Many other individual country cases can be cited. The overall tendency to diminished relative importance of binary non-university institutions, specialist institutions, and separate research academies, is readily explained. As participation in universities spreads, the lesser prestige of a second sector is a growing handicap. Because of economies of scale and inter-disciplinary scope, and the need to be part of a ranked science university to be globally competitive, smaller specialists are pushed towards merger. Research in universities connects more effectively to global science than does research in national laboratories. Yet these logics do not always prevail. There are various single country exceptions to one or more of propositions 1-8 above. Most countries retain some specialist colleges, often in the arts. Likewise, while in Russia and South Korea the role of specialist research academies and institutes has diminished relative to multiversities, the academies are robust in Germany and France. In China the Academy has its own university. Some binary systems have proven to be relatively robust, for example in Germany, Netherlands and Finland. Perhaps this can be explained partly by the desire to protect the character of the academic universities. Nevertheless, it is significant that in all three cases the second sector institutions have evolved as multi-disciplinary institutions, and all three now have 'university' in their titles (e.g. 'University of Applied Science'), suggesting a form of partial convergence.

In observing the overall trends in institutional form and system shape, the waters have been somewhat muddied by an implosion of the title ‘university’, which in some systems is now attached to small private colleges. There are also cases of greater real diversity. Aside from the proliferation of online offerings, for-profit teaching colleges are spreading (e.g. India, UK), though in high participation national systems they lack prestige and remain marginal. Some countries, including China, are creating new technical-vocational institutes. Yet this follows a consolidation in China which saw newly standardized classifications and reduced diversity of type. The United States is another contrary case. On one hand there is upward and downward academic drift, via mergers and new programmes, leading to larger, more comprehensive institutions that operate across a broader cross-section of the higher education field (Johnstone, 2010). On the other hand, 28 per cent of all students are in online programmes alongside or in place of on-site delivery; public and private colleges have sustained their share of the enrolment; and between 1990 and 2014 the proportion of all students who were in research universities fell from 32 to 28 per cent (Cantwell, 2018). Yet the multiversity WCU, which began in the US, dominates in terms of prestige and resources.

Regardless, the main points are these: (1) notwithstanding diversity in non-research university institutions, the research university and especially the WCU stand higher; and (2) WCUs and would-be WCUs in each national system are becoming more like each other. The worldwide adoption of the multi-purpose, multi-disciplinary conglomerate kind of university is not a process of mimetic conformity to the norms of an invisible ‘world society’ or a ‘world polity’, as stated by institutional theory (e.g. Schofer and Meyer, 2005). Rather it is more usefully understood as agency driven, powered by the inner dynamics of institutional growth in the striving for the multiple WCU goals of research power, social-institutional status and shared common goods—in the context of an expansionary global network in which there is scope for strategic innovation at both national systemic and WCU level, as well as imitation. National systems, and WCUs, have considerable scope to choose the most functional forms and practices, reworking them with their own histories and resources.

More of the same. Despite this scope, the tendencies to similarity of form are very visible. Rankings have installed a crisp global homogenization with clear-cut drivers of policy and institutional strategy because they embody common and co-related tendencies that are more deeply felt than the often clumsy and superficial techniques of the rankers: standardization of scientific knowledge within the medium of global English; inter-university comparison, emulation and convergence; and ever-growing collaboration across borders.

Global homogenization has well-known downsides (Marginson and Ordorika, 2011). It reinforces asymmetrical power in world higher education, with intellectual costs: it weakens the visibility, credibility, resources and viability of all disciplines and outputs that fall outside publication and citation counts; it marginalizes single-discipline institutions and others that do not fit the mold such as technical-vocational institutes;

it blatantly excludes non-English language scholarship. The last is a major cost, compounded by the paucity of translation of non-English language works into global English, compared to translation in the reverse direction. Yet common language, and similar organizational forms in higher education, also facilitate cross-border collaboration between countries and between WCUs. Standardized forms speed people mobility, underpin joint publication, and ease the framing of academic programs and negotiation of partnerships. Paradoxically, this fosters more extensive encounters with culturally diverse practices that become visible within larger common systems—though having just one global language, English, limits the depth of exchange.

4. 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.

Open network structure. Global research and scholarship is a mix of openness and closure. Much of pre-codified and codified academic knowledge is accessible on the Internet without restriction, facilitating 'left field' initiatives. Most academic journals are accessed at relatively low user cost through university libraries. Yet military-security research (which may be an increasing proportion of all scientific research) and commercial research are not freely accessible; and the dissemination and use of knowledge are more common and accessible than knowledge production. Research and scholarly inquiry are structured by rules, conventions and intellectual property; by publishers' business agendas and collegial academic gatekeeping. National and global knowledge are also structured by the university hierarchy. Knowledge produced and doctoral degrees awarded from the most prestigious and resourceful WCUs have higher visibility and status than knowledge and degrees from elsewhere. The hierarchy of WCUs, articulated by ranking, articulates an evolving worldwide system for valuing artefacts of knowledge, slotting higher education into national and global relations of power and economic value-creation (Marginson, 2008; Rietz, 2017). In addition, as discussed above, there are inequalities in the ascribed value of knowledge from different countries and in different languages, and a hierarchy of value between the disciplines.

Yet from the point of view of commonness—openness, freedom, equality, solidarity—this is also a 'glass half full'. In global space, closure is never as complete as in nation-bound structures (Marginson, 2011). There are many points of entry to the circuits of knowledge creation, collaboration and dissemination. Above all, networks encourage the continual expansion of connections while facilitating 'flat' horizontal relationships. Castells (2000) explains the economic and social logics of networks. Each successive node is added at negligible cost, adds value to the existing nodes, multiplies the potentially fruitful connections and cheapens the average cost of connections across the network. Networks expand naturally towards complete inclusion while calling new agents into being. At one and the same time they cluster at the principal nodes, empowering those notes, while also spreading the web of inclusion to every corner. Castells (2000, p. 225) notes the Internet ‘allows metropolitan concentration and global networking to proceed simultaneously’. The principal nodes in the global economy are not so much countries as global cities. The principal nodes in higher education and science are the WCUs located in those cities. But the flat structure of networks ensures that all nodes, even the newest and smallest, can deal with every other node on merit without being constrained by the principal nodes.

In their study of the development of the global science network after 1990, Wagner, Park and Leydesdorff (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 that there has been a vast expansion in the number of countries that were part of the ‘dense centre of the network’. The core was just 35 countries in 1990 but expanded rapidly to reach 64 in 2005 and then 114 nations only six years later in 2011, ‘with many developing countries also joining the core group, meaning that new members find it relatively easy to join’ (p. 6). This coincided with a doubling in the number of countries that invest 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 the growth in total network size the average distance between countries has diminished and network diameter remains at three, meaning the whole network can be traversed in three steps, from a node on one edge of the network to a node on the other edge. Further:

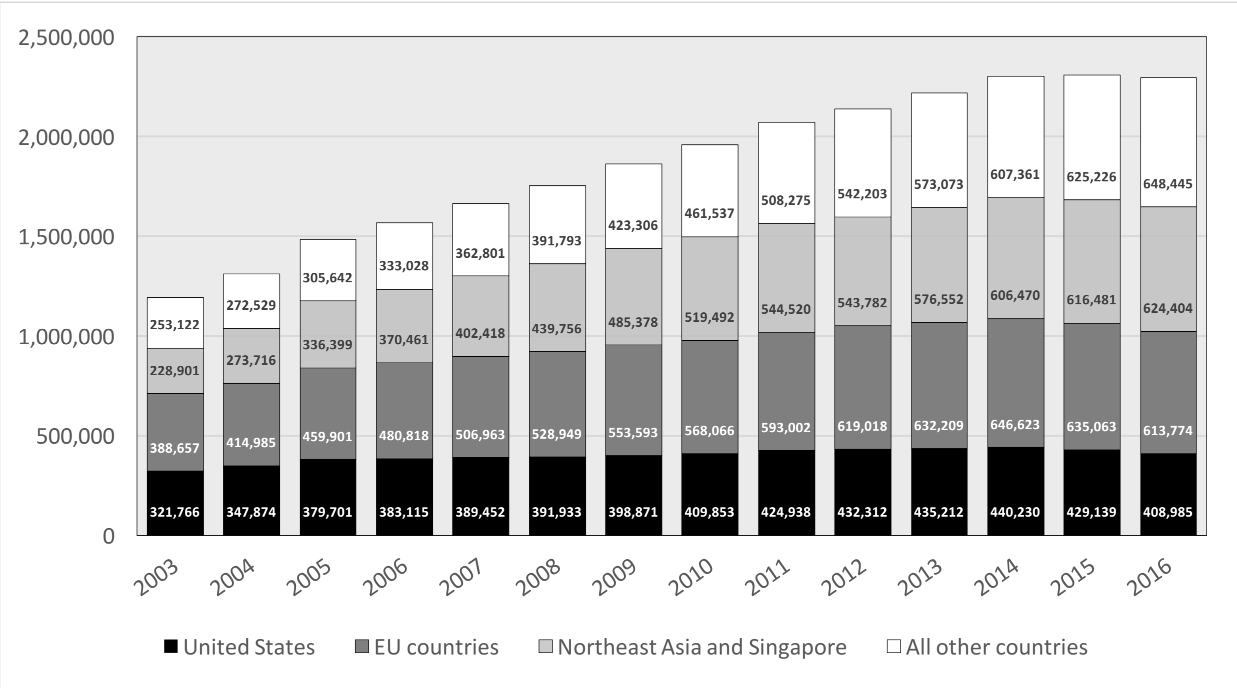
> Against expectation the average betweenness among nations has dropped from 0.26 to 0.10 suggesting fewer nodes dominate the network, or, in other words, power is more diffused throughout the network in 2011 than was the case in 1990. New entrants are not clustering around the scientific ‘leaders’. This can also be interpreted as representing a more open network than was found in 1990 (Wagner, Park and Leydesdorff, 2015, p. 6).

‘Many nodes operate effectively in the network’ (Wagner, et al., 2015, p. 7). ‘New entrants are able to find collaborators without having to pass first through a core of highly powerful (or central) nodes’. Global science ‘may be operating as an open system’ (p. 8).

Wagner and colleagues show that global science has become more pluralized as well as more open. Network structure and agency both facilitate this pluralization. ‘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 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' (p. 1, p. 6). 'Power is being dispersed throughout the network' (p. 6). The global science network is something different, something new. This in turn has implications for the relationship between science and the nation-state—and hence for the relationship between WCUs everywhere, and their states:

> 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 and Leydesdorff, 2015, p. 1).

Figure 6. Annual number of published science papers 2003-2014:
United States, EU countries, Northeast Asia and Singapore, all other countries



Source: Prepared by author on the basis of data from NSB (2018), Table A5-27. Original data from Scopus. Papers for 2015 and 2016 appear incomplete. It is certain that in future compilations the volumes for those years will increase.

Growth of published science

Figure 6 summarizes recent growth in the aggregate output of published research papers, by region. Though mature national research systems do not rapidly growth their output—in one case, Japan, total output fell by 12.7 per cent between 2011 and

2016—there is some growth in the United States and more in the EU countries. However, the feature of Figure 6 is the expansion of the emerging science systems in the upper two sections of the graph, Northeast Asia and Singapore, and also the rest of the world. Growth is so robust in these categories that it continued in 2015-2016 despite the data gaps (see note to table).

Table 7 lists all of the countries that produced more than 10,000 papers in 2016, in order of the annual rate of growth in papers over 2006-2016. The overall growth of published science at world level was 3.9 per cent per annum. Most 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. Other emerging national systems that stand out include Iran, which moved from 10,703 to 40,974 papers, an annual growth rate of 15.1 per cent, and Malaysia which achieved 20,332 papers in 2016 and an exceptional 20.2 per cent annual growth, albeit from a low base. Just below 10,000 is Saudi Arabia (9232 papers, 17.1 per cent). In the world's fourth largest country by population, Indonesia, which has moved decisively into the middle income bracket, science has begun its long climb upwards from a low base, moving from 619 to 7729 papers (28.7 per cent) (NSB, 2018, Table 5-22).

Table 7. 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 %
Malaysia	3230	20,332	20.2
Iran	10,073	40,974	15.1
Romania	3523	10,194	11.2
India	38,590	110,320	11.1
Egypt	3958	10,807	10.6
China	189,760	426,165	8.4
South Africa	5636	11,881	7.7
Russia	29,369	59,134	7.2
Portugal	7136	13,773	6.8
Brazil	28,160	53,607	6.6
Czech Republic	8839	15,963	6.1
South Korea	36,747	63,063	5.5
Denmark	8536	13,471	4.7
Poland	21,267	32,978	4.5
Mexico	9322	14,529	4.5
Australia	33,100	51,068	4.4
Norway	7093	10,726	4.2
WORLD	**1,567,422**	**2,295,608**	**3.9**

system	Papers 2006	Papers 2016	Annual growth %
Italy	50,159	69,125	3.3
Singapore	8205	11,254	3.2
Austria	9155	12,366	3.1
Spain	39,271	52,821	3.0
Switzerland	16,385	21,128	2.6
Belgium	13,036	16,394	2.3
Germany	84,434	103,122	2.0
Netherlands	24,461	29,949	2.0
Sweden	16,634	19,937	1.8
Canada	49,259	57,356	1.5
Finland	9204	10,545	1.4
France	62,448	69,431	1.1
United Kingdom	88,061	97,527	1.0
Taiwan	25,246	27,385	0.8
United States	383,115	408,395	0.7
Israel	11,040	11,893	0.7
Greece	10,684	10,725	0.0
Japan	110,503	96,536	- 1.3

Source: Data prepared by author from NSB (2018), Table 5-22.

More productive WCUs. Those are the patterns at national level. What of individual WCUs? Between 2009 and 2015, the number of universities producing more than 1000 science papers in the previous four years rose from 685 from 903. The number with more than 5000 papers rose from 126 to 190. The number of very large science engines that published over 10,000 papers doubled from 25 to 50. The number of universities producing high citation science also grew, as did the number of high citation papers produced by each of the research leaders. (The number of top 10 per cent cited papers grows automatically in proportion with total research output). In 2015, 211 WCUs had more than 500 papers in the preceding four years that were in the top 10 per cent of their disciplinary field by citations. There were only 138 such universities six years earlier in 2009 (Leiden University, 2018). But as Table 8 shows, the main story is also the pluralization of high quality science in WCUs.

Pluralization of science

Between 2006 and 2012 there was a modest pluralization of WCUs in national terms. Using the relative definition of a WCU, the number of specific systems with universities in the world top 500 increased from 37 in 2004 to 46 in 2017 (ARWU, 2017). Using the absolute definition of a WCU, the Leiden data show that the number of countries with universities producing more than 5000 science papers in the previous four years rose from 23 countries in 2009 to 27 in 2012. The share of the universities producing more than 5000 papers that were *not* from the United States or United Kingdom rose from 54.0 to 62.1 per cent. More significant, however, is the more plural production of high quality science papers.

Table 8. WCUs producing over 1000 high quality science papers, defined as papers in top 10 per cent of their field by citation rate, in 2012-2015. (Institutions with over 1000 such papers in both 2006-09 and 2012-15 are in normal type, those doing so in 2012-15 *only*, newcomers, are in bold)

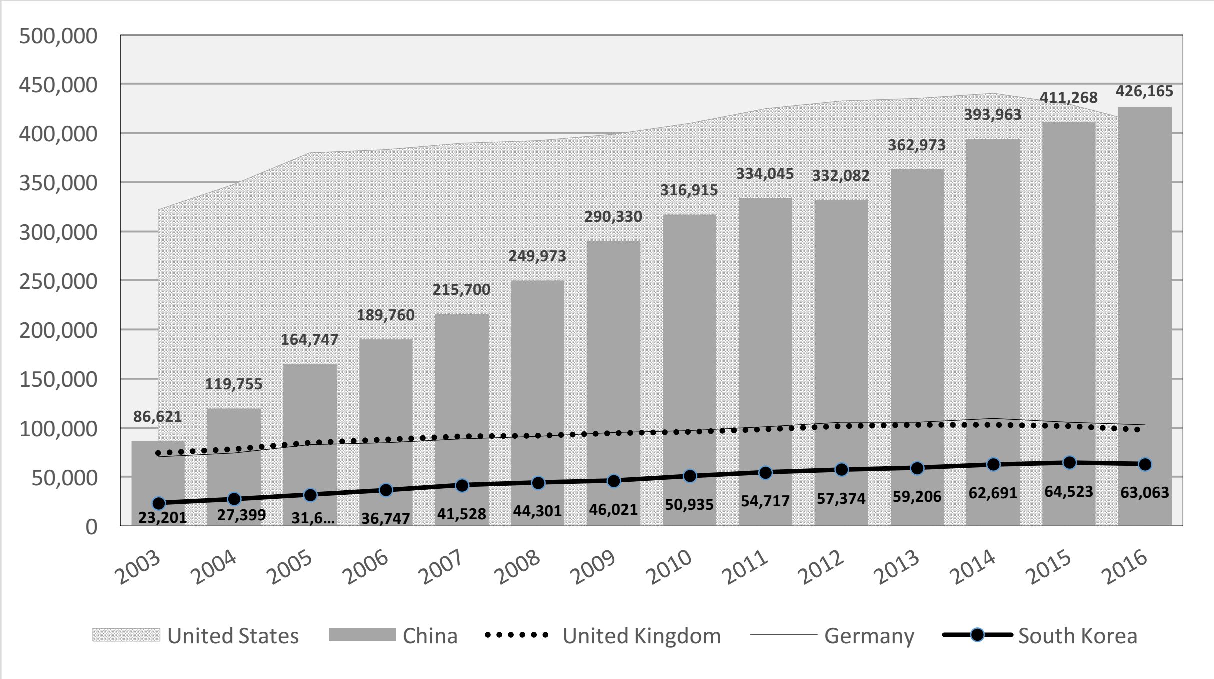
UNITED STATES		Number of papers
Harvard U	USA	7134
Stanford U	USA	3372
U Michigan	USA	2798
Johns Hopkins U	USA	2649
UC Berkeley	USA	2628
Massachusetts IT	USA	2565
U Washington, Seattle	USA	2436
UC Los Angeles	USA	2398
U Pennsylvania	USA	2247
UC San Diego	USA	2217
Columbia U	USA	2168
Yale U	USA	2130
UC San Francisco	USA	1967
Duke U	USA	1828
Northwestern U	USA	1813
U Wisconsin-Madison	USA	1766
U Minnesota, T. Cities	USA	1649
U Pittsburg	USA	1629
U North Carolina, C.H.	USA	1543
UC Davis	USA	1493
Cornell U	USA	1468
Washington U, St L.	USA	1467
U Texas, Austin	USA	1451
New York U	USA	1450
Ohio State U	USA	1425
U Chicago	USA	1393
Pennsylvania State U	USA	1363
U Illinois Urbana-C.	USA	1319
U Texas HSC, Houston	USA	1307
U Florida	USA	1206
U Southern California	**USA**	1171
Princeton U	**USA**	1170
Vanderbilt U	**USA**	1159
Caltech	USA	1119
Emory U	**USA**	1076
Rutgers U	USA	1008
U Maryland, C. Park	**USA**	1000

OTHER ANGLOSPHERE		Number of papers
U Toronto	CANADA	2980
U British Columbia	CANADA	1730
McGill U	CANADA	1407
U Alberta	**CANADA**	1097
U Oxford	UK	2570
U College London	UK	2357
U Cambridge	UK	2274
Imperial College London	UK	1871
U Manchester	**UK**	1273
King's College London	**UK**	1231
U Edinburgh	**UK**	1078
U Melbourne	AUSTRALIA	1518
U Queensland	**AUSTRALIA**	1443
U Sydney	**AUSTRALIA**	1416
Monash U	**AUSTRALIA**	1109
U New South Wales	**AUSTRALIA**	1080
EAST ASIA		
Tsinghua U	**CHINA**	1768
Zhejiang U	**CHINA**	1762
Shanghai Jiao Tong U	**CHINA**	1538
Peking U	**CHINA**	1403
Fudan U	**CHINA**	1224
Huazhong U S&T	**CHINA**	1045
Sun Yat-sen U	**CHINA**	1006
National U Singapore	SINGAPORE	1597
Nanyang Technologic. U	**SINGAPORE**	1413
U Tokyo	JAPAN	1333
Seoul National U	**STH KOREA**	1182
WESTERN EUROPE NEI		
ETH Zurich	SWITZERLAND	1596
U Zurich	**SWITZERLAND**	1106
Ecole P.F. Lausanne	**SWITZERLAND**	1013
Katholieke U, Leuven	BELGIUM	1459
Ghent U	**BELGIUM**	1207
U Copenhagen	**DENMARK**	1432
U Utrecht	NETHERLANDS	1382
U Amsterdam	**NETHERLANDS**	1234
Karolinska Institute	**SWEDEN**	1056
Ludwig Maximillians U	**GERMANY**	1005
U Paris VI P&M Curie	**FRANCE**	1005

NEI = not elsewhere included.
UC = University of California.

Source: Author, using data from Leiden University (2018)

Figure 7. Annual number of published science papers, 2003-2016
United States, China, Germany, United Kingdom, South Korea



Source: Prepared by author on the basis of data from NSB (2018), Appendix Table 5-27. Original data from Scopus. Inclusion of papers for the most recent years 2015 and 2016 appears incomplete. It is likely in future compilations the number of papers for those years will increase for all countries.

Table 8 refers to individual WCUs and focuses on papers in the top 10 per cent of their disciplinary field on the basis of citation rate. Almost all universities in the table saw the number of high citation papers increase—for example Harvard's rose from 6036 in 2006-2009 to 7134 in 2012-2015, Oxford's rose from 1791 to 2570, and so on. The United States remains much the strongest national system in terms of high citation science. However, the number of countries with WCUs producing one thousand or more of these high quality papers rose from nine to 15; and Table 8 shows that the main growth of high volume high citation universities has been outside the United States, in East Asia, Western Europe, Australia and to some extent UK. Universities in bold are the 'new kids on the block', those that produced 1000 high citation papers in 2012-2015 but not 2006-2009. All seven entries from China are new. The number of universities in Western Europe with over 1000 papers jumped from three to 11, and in Australia from one to five (Leiden University, 2018).

Rise of East Asia and Singapore. Within the overall global pattern of growth and dispersion of research capacity, the main global tendency is the rise of East Asia together with the outlier of the Chinese civilizational zone, Singapore, to the position of third major R&D region, joining North America and Western Europe/UK. As Table 1 shows, in 2015 China's spending on R&D was more than four fifth that of the United States. Figure 7 shows that while in 2003 China produced less than 30 per cent of United States' scientific output, it passed the United States' level in 2016. The number of papers multiplied by 4.9 in 13 years. Over this period South Korea's multiplication factor was 2.7 and Korean research output began to approach the scale of the older science systems of Germany and UK.

Table 9. Average citations to science and engineering papers, selected national systems, 1996-2014 (two-year intervals)
World average citation rate = 1.00

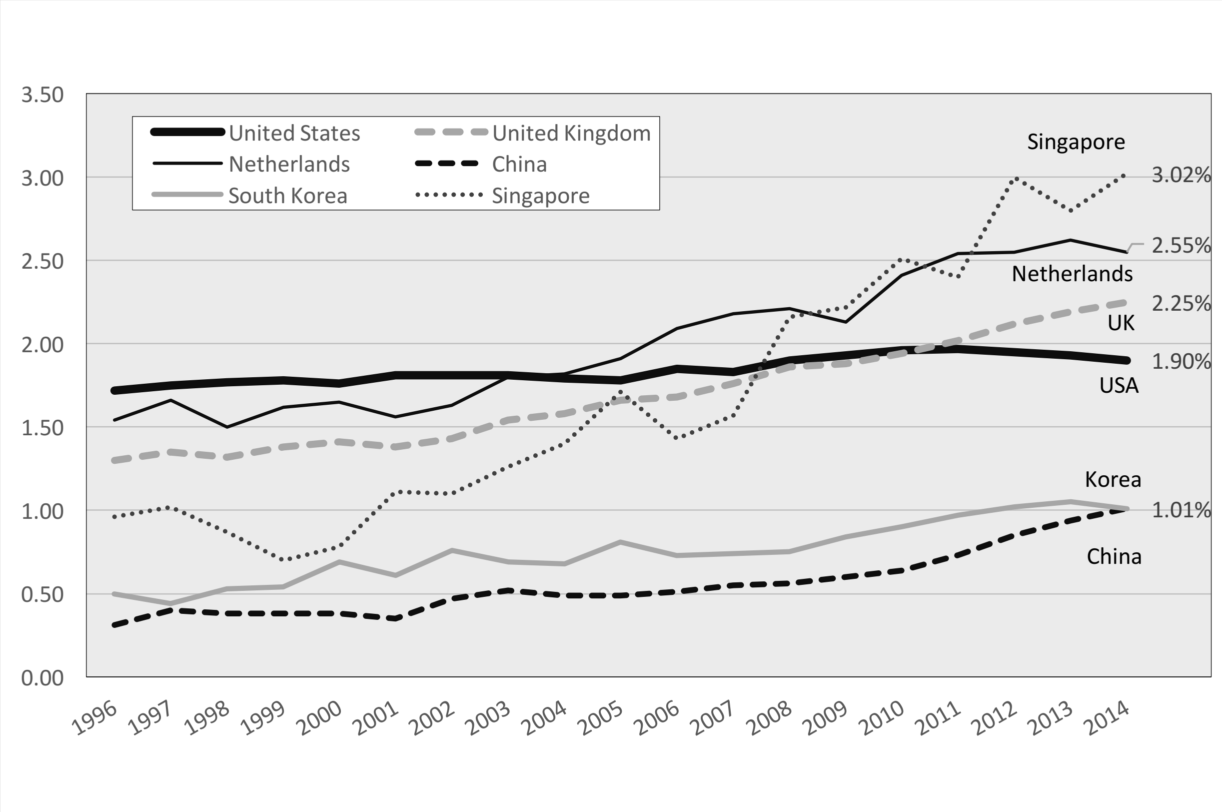
	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014
United States	1.41	1.43	1.41	1.42	1.41	1.43	1.45	1.48	1.44	1.42
United Kingdom	1.22	1.25	1.27	1.29	1.33	1.39	1.43	1.49	1.52	1.53
Germany	1.05	1.05	1.08	1.10	1.14	1.20	1.25	1.33	1.33	1.34
Japan	0.77	0.80	0.77	0.79	0.82	0.82	0.84	0.84	0.85	0.87
China	0.46	0.48	0.54	0.58	0.62	0.64	0.69	0.73	0.88	0.96
South Korea	0.79	0.82	0.89	0.92	0.89	0.88	0.92	1.04	1.08	1.06
Taiwan	0.85	0.83	0.88	0.94	0.94	0.98	1.02	0.98	1.04	0.97
Singapore	1.00	1.08	1.06	1.15	1.23	1.38	1.55	1.75	1.91	1.83

Science includes some social science.
Source: Author, using data from NSB (2018), Table A5-50

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 WCUs, like Singapore's, would be more highly placed if the ARWU did not use Nobel Prizes as an indicator). China's future scientific capacity will be twice further boosted, by investments in the 'Double World-Class' and 'One Belt One Road' programmes. The pipeline effect of current national investments alone will ensure that scientific output continues to grow rapidly in China and Singapore, and probably in South Korea; though spending constraints are a brake in Taiwan and especially in Japan.

The quantitative growth in East Asian science has been followed by its lift in quality. Table 9 traces the longer-term evolution of average citation rates in each national science system, a proxy for relative research quality. The citation rate of United States-authored papers remained constant between 1996 and 2014, while the United Kingdom and Germany improved significantly. However, the main action is in the lower half of the table. The world rate of citation of East Asian research has risen sharply since the mid 1990s, though less in Japan, where spending on universities plateaued, than in the other countries. Singapore's citation rate passed the United States and the United Kingdom in 2008 and reached an exceptional 1.83 in 2014. Taiwan passed the world average citation rate in 2008 and South Korea in 2012. China' average rate was a low 0.46 in 1996 but by 2014 had reached 0.96, just below the world average, rapid improvement across the large system.

Figure 8. 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
(World average = 1.00)



Source: Author, using data from NSB (2018), Table A5-51

Figure 8 traces trends between 1996 to 2014 in the proportion of science and engineering papers that were in the top 1 per cent of their disciplinary field on the basis of citation rate. In all countries shown in the graph there was growth in the weight of the top 1 per cent papers over the period. The United States, the world leader in 1996, moved from 1.75 to 1.90 per cent. In 2005 it was passed by the Netherlands, chosen here as typical of the small-to-medium-size high quality science systems in Northwestern Europe. In 2011 the US was passed by the United Kingdom (UK), which has concentrated research excellence in its leading universities through successive iterations of the Research Assessment Exercise/Research Excellent Framework. Over the period European countries, including the UK, benefitted from the building of research capability in the European Research Area joint programmes. Many smaller European countries, with a cluster of WCUs and scope to specialize in research, had more than 1.90 per cent of their 2014 papers in the top 1 per cent on the basis of citation: Austria, Belgium, Cyprus, Denmark, Estonia, Finland, Greece, Iceland, Ireland, Norway, Sweden and Switzerland. In larger Germany the proportion of papers in the top 1 per cent was 1.76 per cent, in France 1.61 per cent (NSB, 2018, A5-51).

Table 10. 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 2006-09 to 2012-15 *2006-09 = 1.00*
Tsinghua U	CHINA	819	1768	2.15
Zhejiang U	CHINA	730	1762	2.42
Peking U	CHINA	622	1538	2.47
Shanghai Jiao Tong U	CHINA	644	1403	2.11
Fudan U	CHINA	469	1224	2.61
Huazhong UST	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	STH. KOREA	742	1182	1.59
National Taiwan U	TAIWAN	604	786	1.30
MIT	USA	2091	2565	1.23
U Cambridge	UK	1796	2274	1.27

Source: Author, using Leiden University (2018) data.

The other story told by Figure 8 is again the improvement of quality in East Asia. As in the English-speaking countries, this qualitative improvement shows more strongly in top 1 per cent science than in average citations to all papers, indicating that a WCU concentration policy is at work. Over the 18 years in the graph Singapore lifted the proportion of its papers that were in the top 1 per cent from a low of 0.70 per cent in 1999 to 3.02 per cent in 2014, three times the world average. The Singapore average is unaffected by a layer of second and third tier research universities, as are the larger systems (and the uneven Singapore line, compared to smoother trends in the larger systems, reflects the impact of fluctuations in the annual output of its two WCUs in the data). South Korea, with 50 million people, improved steadily to world average level in 2012; and China with its 1.3 billion people climbed from only 0.31 per cent in 1996 to reach the world average in 2014 with 1.01 per cent of its papers in the top 1 per cent category. Most of China's growth in the proportion of top 1 per cent papers took place in the last five years of the graph. Scientific output in China is still well below the overall quality of Western Europe and the United States, in both average citation rates and the proportion of papers in the top group, but the massive scale of the national system in China, coupled with rapid growth in high citation work, means that a large proportion of the world's future scientific knowledge will come from that country.

Physical sciences STEM WCUs in East Asia. The data in Figure 8 are at national system level. What about trends in the production of high citation science in individual WCUs? Table 10 summarizes the growth of total high citation papers (top 10 per cent of their field) in the leading WCUs in East Asia and Singapore. MIT and Cambridge provide a comparison. At Zhejiang, Peking University, Fudan and Huazhong in China, and Nanyang in Singapore, the dynamism is obvious. Note also that smaller Nanyang is approaching NUS in Singapore.

Table 11. Leading universities in (1) Physical Sciences and Engineering and (2) Mathematics and Complex Computing, based on published papers in the top 10 per cent of their field by citation rate

	University	System	Top 10% papers in Physical Sciences & Engineering
1	UC Berkeley	USA	1176
2	Massachusetts IT	USA	1175
3	Tsinghua U	CHINA	1054
4	Stanford U	USA	976
5	Nanyang TU	SINGAPORE	931
6	Harvard U	USA	875
7	Zhejiang U	CHINA	857
8	U Cambridge	UK	801
9	NU Singapore	SINGAPORE	749
10	U S & T	CHINA	720
11	ETH Zurich	SWIZERLAND	678
12	U Tokyo	JAPAN	649
13	Shanghai JT U	CHINA	638
14	Peking U	CHINA	636
15	Caltech	USA	635

	University	System	Top 10% papers in Maths & Complex Computing
1	Tsinghua U	CHINA	367
2	Nanyang TU	SINGAPORE	259
3	Zhejiang U	CHINA	256
4	Huazhong USA	CHINA	250
5	Massachusetts IT	USA	245
6	Harbin IT	CHINA	236
7	NU Singapore	SINGAPORE	226
8	Stanford U	USA	208
9	Xidian U	CHINA	205
10	Shanghai Jiao T U	CHINA	196
11	City U Hong Kong	HK SAR	188
12	U Texas, Austin	USA	187
13	South East U	CHINA	184
14	UC Berkeley	USA	184
15	Beihang U	CHINA	177

Source: Author, using Leiden University (2018) data.

Table 11 lists the top 15 WCUs in physical sciences STEM, in terms of papers in the top 10 per cent by citation rate. China had over half the top 15 universities in mathematics and computing in 2012-2015. Tsinghua was the clear world number 1, with Singapore's Nanyang second. The highest placed US university, MIT, was fifth. In the larger physical sciences and engineering group the US had the top two WCUs, Berkeley and MIT; but China like the US had five of the top 15. The two Singapore universities were in the world top 15 in both discipline clusters. Joining the two columns in Table 11, Tsinghua with 1421 top 10 per cent papers just shades MIT with 1420 papers as the world's top STEM university—though the US still had four of the top seven physical sciences STEM universities when the columns are combined. If the measure is switched to the much smaller group of top 1 per cent papers, MIT takes the overall lead in combined physical sciences STEM, followed by Stanford, Berkeley, Harvard and Nanyang, all ahead of Tsinghua. However, Tsinghua is world number one in top 1 per cent papers in mathematics and computing alone (Leiden University, 2018).

Across East Asia the physical sciences STEM disciplines have been the primary focus of nation-state investment. The achievement in those disciplines is not confined to the small number of very top WCUs in Tables 10 and 11 but extends across the WCU sector. Table 12 shows that at the level of the system as a whole, in data now four years old, China had already moved close to American levels of top 1 per cent papers in chemistry and mathematics. There are now two exceptionally strong zones in world research in physical sciences STEM, on each side of the Pacific. The rise of East Asia has somewhat crowded the United States in physical sciences STEM. There has been a slight decline in overall United States' performance as measured by average citation rates, and top 1 per cent papers.

Table 12. Proportion (%) of all science and engineering papers that were in the top 1 per cent of their field by citation rate, United States, China and EU, 2004 and 2014

Disciplinary field	UNITED STATES 2004 %	UNITED STATES 2014 %	CHINA 2004 %	CHINA 2014 %	EUROPEAN UNION 2004 %	EUROPEAN UNION 2014 %
Computer Science	2.10	2.21	0.46	1.45	0.77	0.96
Astronomy	1.79	2.18	0.23	1.08	1.18	1.25
Medical Sciences	1.93	2.10	0.33	0.56	0.97	1.44
Physics	1.89	2.07	0.67	0.88	1.10	1.41
Biological Sciences	1.67	2.00	0.21	0.63	1.09	1.38
Geo-sciences	1.47	1.92	0.62	1.07	1.30	1.46
Agricultural Sciences	1.51	1.91	0.70	1.03	1.32	1.53
Engineering	1.93	1.79	0.42	1.09	1.26	1.15
Chemistry	1.87	1.47	0.69	1.36	1.03	0.97
Mathematics	1.78	1.40	1.28	1.30	1.01	1.25
Psychology	1.34	1.26	0.64	0.85	0.97	1.12
All fields	1.79	1.90	0.49	1.01	1.05	1.28

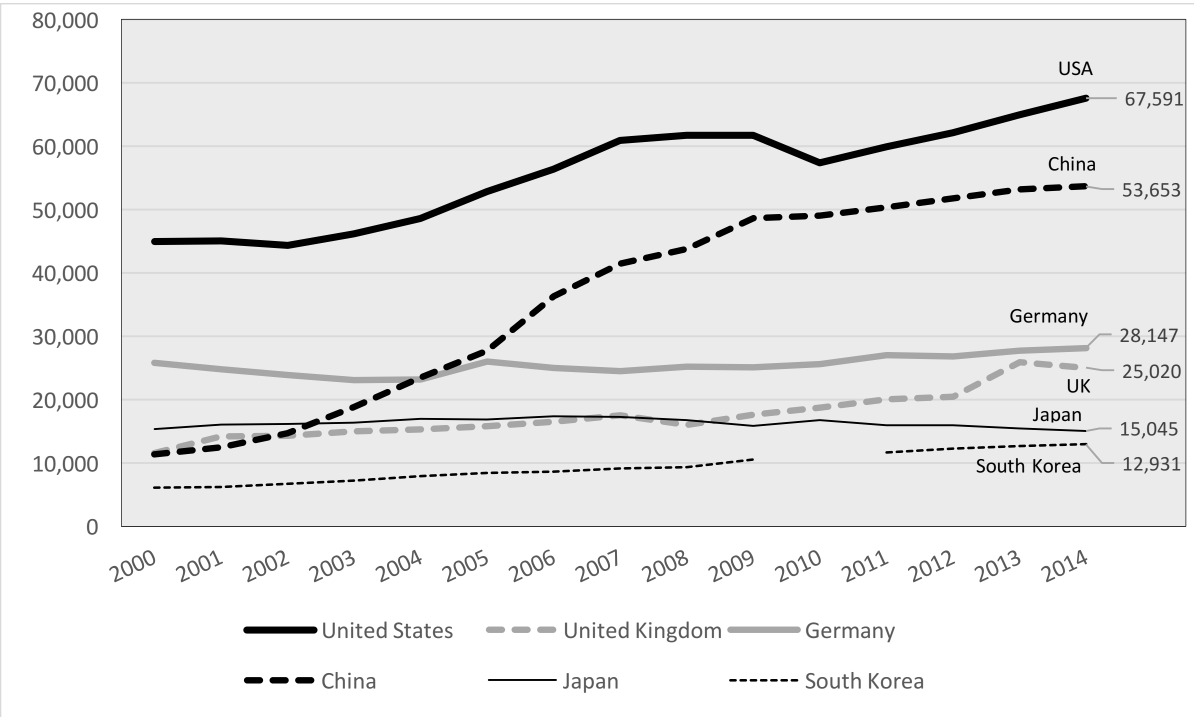
Grey tone indicates declines in proportion of papers that were in the top 1 per cent of their field between 2004 and 2014.
Source: Author using data from NSF (2018), table 5-48

Table 9 showed that the overall citation rate of US science has remained constant since the mid 1990s. However, between 2000 and 2014 average citations in US engineering dropped from 1.37 to 1.34, in chemistry from 1.54 to 1.27, in physics from 1.44 to 1.42 and in mathematics from 1.43 to 1.22 (NSB, 2018, Table A5-49). Table 12 shows the proportion of all US papers in the top 1 per cent of their field lifted from 1.79 per cent in 2004 to 1.90 per cent in 2014, compared to 1.28 per cent in the EU in 2014, and 1.01 per cent in China, at the world average. Nevertheless, in engineering the proportion of US papers in the top 1 per cent fell from 1.93 to 1.79 per cent, in chemistry from 1.87 to 1.47 per cent, and in mathematics from 1.78 to

1.40 per cent. China improved sharply in all three disciplines. Given current investments, plus the upward trajectory in the volume of high citation papers, it looks likely that in the next decade China and Singapore will move past the United States in the volume of top 1 per cent work in physical sciences STEM, if not in the rate of such work. It is unlikely that the present capacity building initiatives in American engineering research at Harvard and elsewhere will be enough to preserve US primacy.

It is important to note that this is a crowding effect within the fixed limits of the top 1 per cent category and not a sign of any absolute deterioration in American science, which for the most part continues to improve in not just absolute but relative measures of quality. Table 12 shows strong growth between 2004 and 2014 in the proportion of United States' papers that were in the top 1 per cent in the STEM disciplines astronomy, physics and computing, as well as in other disciplines: geosciences, agriculture, biological sciences and medicine. Likewise, average citation rates rose in computing, astronomy, agriculture, biological and life sciences, medicine and psychology (NSB, 2018, Tables 5-48 and 5-49).

Figure 9. New doctoral degrees, all disciplines, selected countries: 2000-2014



Series break for South Korea in 2010.
Source: Author, using data from NSB (2018), table A2-38.

Discipline imbalance. Further, when all disciplines are included in the comparison, as a group the American WCUs are not just well ahead of the rest of the world in the quantity of high quality work, they emerge as more balanced than their East Asian counterparts, as do European universities. East Asian research systems are highly skewed to physical sciences STEM, less strong in biological sciences, and weak in medical sciences, and (less surprisingly given the language factor) in English language social sciences and humanities.

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 (29.3 per cent), and biological and other life sciences, excluding agriculture. In the EU the combined proportion in medical, biological and other life sciences was 40.7 per cent. In China the combined proportion was 27.5 per cent (13.3 per cent in medical research). 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). Leiden University (2018) data for 2012-2105 show that in top 10 per cent papers in biomedical and health sciences, the highest ranked Chinese university was Shanghai Jiao Tong at 117th. Whereas the leader, Harvard, had 726 high citation papers in biomedical and health sciences, Shanghai Jiao Tong had just 30.

In social sciences and humanities, the top ranked Chinese institution in the Leiden ranking was Peking University in only 151st place. Nevertheless, given that most work in the humanities and non-quantitative social sciences is in national languages, the global English-language journal comparison in those disciplines must carry little weight. In those disciplines the global comparison with English-medium WCUs in Singapore and Hong Kong SAR is more meaningful than is the comparison with WCUs in China, South Korea or Japan.

Table 13. Earned doctoral degrees in science and engineering, and other fields, countries producing more than 10,000 doctorates, 2014 or nearest year

Country	Doctoral degrees in science and engineering	Doctoral degrees in other fields	All doctoral degrees	S&E doctorates as proportion of all %
USA	39,834	27,757	67,591	58.9
China	34,103	19,550	53,653	63.6
Russia	19,340	17,193	36,533	52.9
Germany	14,625	13,522	28,147	52.0
UK	14,271	10,749	25,020	57.0
India	13,144	8686	21,830	60.2
Brazil	9124	7621	16,745	54.5
Japan	6743	8302	15,045	44.8
France	10,023	3706	13,729	73.0
South Korea	6032	6899	12,931	46.6
Spain	6708	4181	10,889	61.6
Italy	6185	4493	10,678	57.9

Source: Author, using data from NSB (2018), Table 2-37

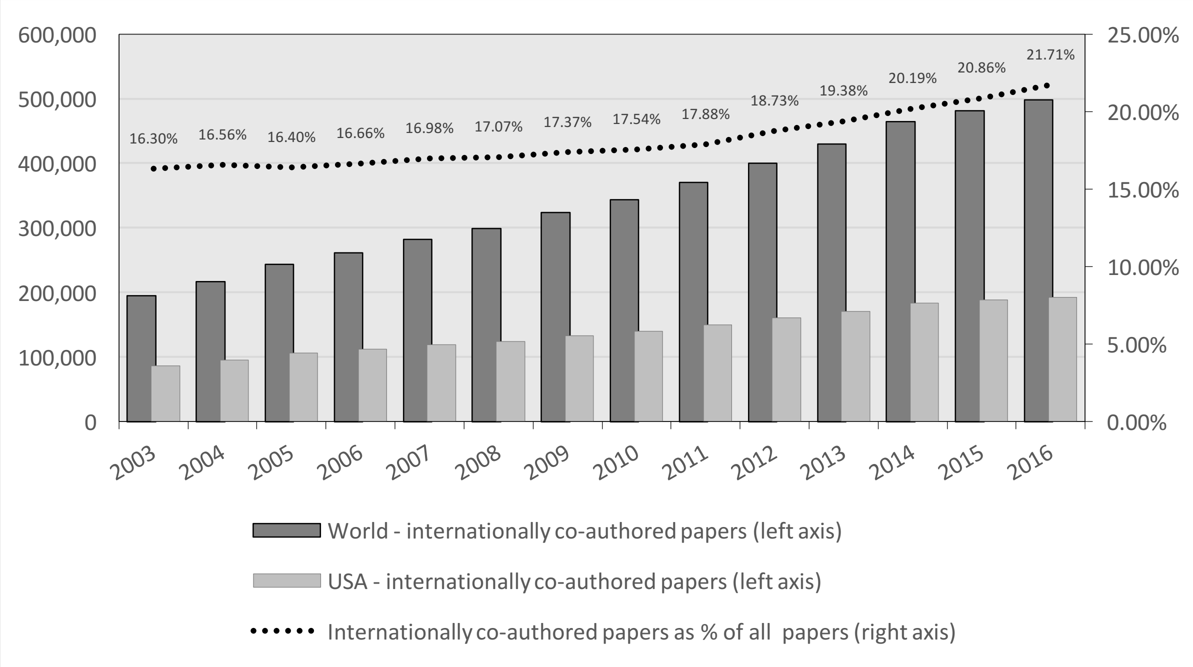
There are more favourable grounds for cross-border research conversations between East Asia, Europe and North America in physical sciences STEM than in other disciplines. The relatively weak engagement of the Chinese civilizational zone (except Hong Kong SAR) in global conversation in humanities and social sciences may inhibit the development of hybridist common thinking in such strategic areas as governance and political culture, and international relations, not to mention philosophy—unless Europe/UK and North America become more Asia-lingual, and ultimately bi-cultural, as Asia has become. 'The West' should become bi-cultural. The alternative is to know only part of what is being said.

Regardless of the evolution of North America and Europe, an expanding share of all doctoral graduates will come from East Asia and India in future. China is now the second largest source of doctorates on the world scale. Between 2000 and 2014 the number of doctoral graduates from the United states increased by 50 per cent, the number from the UK multiplied by 2.2 times, but the number from China multiplied 4.7 times (Figure 9). China's doctoral numbers in science and engineering in 2014 were already 85.6 per those of the United States (NSB, 2018, Table A2-37), as Table 13 shows. The pluralization of doctoral training, like the pluralization of science and WCUs of which it is part, will encourage both greater cross-border mobility and more extensive and intensive cooperation between WCUs, including joint publication which is partly sustained by mobile doctoral students.

Global collaboration in research

What do the data show about cross-border collaboration? This can be examined in terms of both national level data on cross-border collaboration and citation, and data on collaborative publication by individual WCUs. Both kinds of data will be considered.

Figure 10. Growth in annual number and proportion of internationally co-authored papers in science and engineering, 2003 to 2016, World and United States



Science includes some social science.
Source: NSB (2018), Table A5-42

The world picture. Data on jointly-authored publications show that the number of collaborative publications is expanding rapidly (see Figure 10), and their proportion of all published science also grows (Figure 10, Tables 14 and 16). Cross-national citation of papers is also increasing, suggesting that within the global knowledge circuits, published research in each country has a growing influence on researchers in other countries. At the same time the incidences of both cross-border collaboration in publications, and cross-border border citation, are uneven between disciplinary fields, and also vary between countries.

Wagner, Park and Leydesdorff (2015), using Web of Science data, find that at world level internationally collaborative papers as a proportion of all published science increased 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'. Emerging countries are also playing a growing role in collaboration (p. 1). Using the Scopus data set not Web of Science, the United States' National Science Board (NSB) shows that the number of internationally co-authored papers at world level rose from 194,398 in 2003 to 498,465 in 2016, and advanced from 16.3 to 21.7 per cent of all papers (Figure 10). Over this time period domestic-only collaboration held steady and there was a decline in single authored papers as a proportion of all published papers. Cross-border papers multiplied by 2.6 while total published papers multiplied by 1.9. It is apparent in Figure 8 that the multiplication of cross-border papers in the world (2.6) was more rapid than in the

United States (2.0). However, American internationalization followed the world trend, as the total growth of US papers during this period was 1.4. The proportion of US Papers with international collaborators advanced from 23.3 to 37.1 per cent (Table 14).

Table 14. 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

EUROPE	2003 %	2016 %
Switzerland	54.5	69.2
Belgium	49.0	66.1
Austria	46.3	64.8
Sweden	45.7	64.3
Denmark	47.7	63.3
Netherlands	44.7	61.8
Norway	45.6	61.4
Ireland	46.1	60.9
Finland	41.2	60.4
France	39.6	54.8
Portugal	45.0	54.2
Greece	35.5	52.3
Germany	39.4	51.0
Spain	33.2	50.7
Italy	33.1	47.3
Czech Republic	35.8	41.9
Poland	29.9	31.3
Russia	26.9	25.1

ANGLOSPHERE	2003 %	2016 %
New Zealand	44.5	58.2
United Kingdom	36.9	57.1
Australia	36.9	54.9
Canada	39.0	53.0
United States	23.3	37.1
LATIN AMERICA	**2003 %**	**2016 %**
Chile	52.7	61.7
Argentina	39.2	45.3
Mexico	39.6	42.3
Brazil	27.2	32.5
MIDDLE EAST & NORTH AFRICA	**2003 %**	**2016 %**
Saudi Arabia	34.5	76.8
Egypt	32.7	51.7
Israel	39.9	50.7
Turkey	16.3	22.2
Iran	24.2	20.8

ASIA	2003 %	2016 %
Singapore	35.0	62.8
Pakistan	28.2	49.3
Thailand	48.7	40.7
Malaysia	36.6	38.4
Taiwan	17.5	29.8
Japan	18.9	27.9
South Korea	25.1	27.0
China	15.3	20.3
India	18.1	17.4
SUB-SAHARAN AFRICA	**2003 %**	**2016 %**
South Africa	40.0	52.1

Science includes some social science.
Source: Author, based on data from NSF (2018), Table A5-42

The disciplines vary in the extent to which their papers are internationally authored. Where there are formal programmes for collaboration, and especially where the 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) then the incidence of collaboration rises. In 2016, cross-border authorship was 54.0 per cent of all published papers in astronomy and exceeded 20 per cent in the geosciences, biological sciences, mathematics, physics and chemistry. While physical sciences STEM disciplines are the most global, this is least true of engineering. However, between 2006 and 2016 international collaboration increased 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).

National publication data. Table 14 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 program 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). Policy requires at least three EU member countries in publicly-funded research projects as a condition of funding (Wagner et al., 2015, p. 4). Table 14 shows that the rate of cross-border publishing is highest 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 United States, and most other European countries.

Table 15. WCUs producing over 1000 high quality science and engineering papers (papers in top 10 per cent of field by citation rate), in 2012-2015: proportion (%) of *all* published papers that had international co-authors

UNITED STATES		number and % of all papers with ICA	
Caltech	USA	7304	56.8
Massachusetts IT	USA	12,093	50.2
Princeton U	USA	5721	49.6
Harvard U	USA	31,292	47.3
UC Berkeley	USA	12,329	47.3
U Maryland, C. Park	USA	6915	44.0
UC San Diego	USA	10,763	42.3
Columbia U	USA	11,594	42.2
Cornell U	USA	7483	42.0
Stanford U	USA	12,958	41.1
Yale U	USA	9658	40.5
UC Davis	USA	8771	40.5
Johns Hopkins U	USA	14,249	40.4
UC Los Angeles	USA	11,904	40.1
U Chicago	USA	6220	39.5
Duke U	USA	10,840	39.3
U Florida	USA	8482	38.9
U Illinois Urbana-C.	USA	6771	38.8
U Texas HSC, Houston	USA	6976	38.3
New York U	USA	6835	37.9
U Southern California	USA	6166	37.9
Pennsylvania State U	USA	7842	37.8
U Texas, Austin	USA	6468	37.7
Rutgers U	USA	6405	37.7
U Washington, Seattle	USA	11,814	37.4
Ohio State U	USA	8366	36.6
UC San Francisco	USA	8153	36.5
U Minnesota, T. Cities	USA	8665	35.4
U Wisconsin-Madison	USA	8326	35.4
U Michigan	USA	12,252	34.8
Northwestern U	USA	7018	33.9
U Pittsburg	USA	7974	33.3
U Pennsylvania	USA	8968	32.6
Vanderbilt U	USA	5280	32.3
Emory U	USA	5226	31.9
U North Carolina, C.H.	USA	6630	31.8
Washington U, St L.	USA	5178	30.8

OTHER ANGLO-SPHERE		number and % of all papers with ICA	
U Oxford	UK	20,288	63.9
Imperial C London	UK	16,269	63.8
U Cambridge	UK	17,732	63.4
UC London	UK	18,890	60.0
U Edinburgh	UK	9614	59.9
King's C London	UK	9747	58.2
U Manchester	UK	10,840	55.2
McGill U	CANADA	11,918	54.6
U British Columbia	CANADA	13,238	54.1
U Toronto	CANADA	20,478	51.8
U Alberta	CANADA	9022	48.4
U Sydney	AUSTRALIA	12,526	52.3
U Queensland	AUSTRALIA	11,346	50.9
U Melbourne	AUSTRALIA	12,529	50.4
U New South Wales	AUSTRALIA	9316	50.2
Monash U	AUSTRALIA	9822	49.4
EAST ASIA			
National U Singapore	SINGAPORE	14,005	60.9
Nanyang Technol. U	SINGAPORE	9500	59.6
Peking U	CHINA	9546	36.9
Tsinghua U	CHINA	8316	35.4
Fudan U	CHINA	6131	30.1
Shanghai Jiao Tong U	CHINA	8350	28.7
Zhejiang U	CHINA	8167	28.3
Sun Yat-sen U	CHINA	5075	27.2
Huazhong U S&T	CHINA	4347	25.5
U Tokyo	JAPAN	10,829	35.0
Seoul National U	STH KOREA	7514	28.6
WESTERN EUROPE NEI			
EPF Lausanne	SWITZERLAND	7865	66.8
U Zurich	SWITZERLAND	11,288	66.7
ETH Zurich	SWITZERLAND	12,557	65.2
Katholieke U, Leuven	BELGIUM	14,319	65.0
Ghent U	BELGIUM	11,634	60.2
Karolinska Institute	SWEDEN	12,054	64.1
U Copenhagen	DENMARK	14,215	62.7
U Paris VI P&M Curie	FRANCE	14,200	61.5
L. Maximillians U	GERMANY	10,107	57.5
U Amsterdam	NETHERLANDS	11,504	55.8
U Utrecht	NETHERLANDS	11,314	53.5

Science includes some social science.
ICA = International co-authors; NEI = not elsewhere included. UC = University of California.
Source: Author, using data from Leiden University (2018)

Table 16. Proportion (%) of all published science and engineering papers with international co-authors, leading 20 WCUs in number of total papers, four-year spans: 2006-2009 and 2012-2015

University		Published papers with international co-authors 2006-2009	Proportion of *total* papers with international co-authors 2006-2009 %	Published papers with international co-authors 2012-2015	Proportion of *total* papers with international co-authors 2012-2015 %
Harvard U	USA	47,282	36.2	66,180	47.3
U Toronto	CANADA	28,394	43.7	39,516	51.8
Johns Hopkins U	USA	25,111	33.3	35,295	40.4
U Michigan	USA	26,171	26.9	35,176	34.8
U Oxford	UK	20,323	54.4	31,744	63.9
U Washington Seattle	USA	23,727	28.3	31,618	37.4
Stanford U	USA	21,784	31.7	31,558	41.1
UC London	UK	20,449	50.3	31,460	60.0
U Tokyo	JAPAN	27,892	28.2	30,972	35.0
UC Los Angeles	USA	24,503	31.5	29,655	40.1
Shanghai Jiao Tong U	CHINA	13,246	21.2	29,121	28.7
U Sao Paulo	BRAZIL	20,134	31.7	29,026	40.2
Zhejiang U	CHINA	15,651	22.0	28,828	28.3
U Cambridge	UK	20,142	50.7	27,947	63.4
Duke U	USA	18,658	27.4	27,605	39.3
Columbia U	USA	20,271	31.6	27,496	42.2
U Pennsylvania	USA	20,842	25.6	27,470	32.6
Seoul NU	SOUTH KOREA	17,323	25.3	26,227	28.6
UC Berkeley	USA	19,507	35.4	26,063	47.3
Peking U	CHINA	12,772	32.9	25,867	36.9

Science includes some social science.
Source: Author, using data from Leiden University (2018)

Co-publication is lower in East Asia than in other leading research regions. Saudi Arabian universities have 76.8 per cent collaboration because they employ large numbers of foreign faculty on a part-time basis, which boosts their global research rankings.

Collaboration between WCUs. Table 15 shows the incidence of internationally co-authored papers in those 70 WCUs that produced the largest number of highly cited (top 10 per cent) papers in 2012-15, the list in Table 8. In the United States, with its unequalled opportunities for national collaboration, Caltech, MIT, Princeton, Harvard and UC Berkeley nevertheless exhibit rates of international collaboration above 45 per cent, though the majority of the US universities are in the 30s. In the top US universities the data on strong global connections signify a global leadership role. In China the incidence of cross-border publishing is lower, with Peking and Tsinghua Universities being more internationalized than the other Chinese WCUs. Tokyo University in Japan and Seoul National University in South Korea have rates of co-publishing similar to the range of Chinese universities, with Tokyo more active in co-publication than Seoul. In contrast, as was shown in the national-level data, the two Singapore universities—which have only one other national WCU with whom to work—collaborate at European-style levels. Likewise, as at national level in Europe, the individual European WCUs have high rates of cross-border publication, with the highest rates of collaboration in smaller systems (Leiden University, 2018).

Table 17. Proportion (%) of citations to national publications that were in *international* publications, countries producing more than 10,000 science and engineering papers in 2016: 1996 compared to 2014

EUROPE	1996 %	2014 %
Switzerland	77.6	83.7
Ireland	76.9	83.3
Belgium	72.8	82.2
Greece	64.0	81.3
Austria	72.6	81.2
Sweden	68.9	80.9
Netherlands	70.3	80.8
Denmark	72.2	80.6
Italy	64.7	79.1
Finland	66.8	79.0
Norway	66.5	79.0
Portugal	63.7	76.1
France	64.7	76.0
Spain	60.2	75.2
Germany	60.8	71.9
Czech Republic	58.5	66.3
Poland	52.6	60.0
Russia	50.8	43.4

ANGLOSPHERE	1996 %	2014 %
Canada	70.7	78.2
United Kingdom	63.8	77.2
New Zealand	67.2	76.8
Australia	65.3	74.5
United States	42.3	55.7
LATIN AMERICA	**1996 %**	**2014 %**
Chile	68.4	76.2
Argentina	60.0	75.3
Mexico	63.7	74.3
Brazil	58.8	62.0
MIDDLE EAST & NORTH AFRICA	**1996 %**	**2014 %**
Israel	74.5	82.5
Saudi Arabia	62.4	81.3
Egypt	58.7	75.9
Turkey	57.1	70.7
Iran	55.1	59.8

ASIA	1996 %	2014 %
Singapore	61.9	84.8
Thailand	74.5	78.4
Taiwan	65.5	76.8
South Korea	56.6	72.0
Malaysia	66.8	69.5
Pakistan	61.5	67.3
Japan	52.6	67.0
India	48.5	61.9
China	51.6	37.7
SUB-SAHARAN AFRICA	**1996 %**	**2014 %**
South Africa	61.4	72.5

Science includes some social science.
Source: Author, based on data from NSB (2018), Table A5-42

Rates of co-publication in British WCUs are akin to those in continental Europe and higher than those in other Anglophone WCUs. This is despite the fact that the UK WCUs have many potential domestic partners, underlining the intensity of the UK's engagement in the European Research Area, which is now at risk because of Brexit.

Table 16, which lists the twenty WCUs that produced the most published research papers in 2012-15, shows that in the six years from 2009, in every WCU there was a substantial increase in the number and proportion of papers with international co-authors. The average increase in the international share of each university's papers was almost 9 per cent, well over 1 per cent a year. The rate of increase was slower in China, Korea and Japan than it was in the English-speaking countries and Brazil (Leiden University, 2018).

Cross-border citations. The expanding role of global science also shows itself in the relative growth in cross-border citations. Table 17 records the proportion of citations to each nation's publications that were from abroad,. Large countries, with a significant part of total citations and consequently of citations of their own publications, tend to have lower values in Table 17, all else equal. The high quality smaller research systems in Europe concentrate at the top end of the table. When a mature science system's share of total world output falls, this increase the share of its citations from international sources, all else equal: for example, the US, UK, Germany and France (NSB, 2018, Table A5-47). When a nation rapidly increases its domestic production relative to the world, this reduces the proportion of its citations from international sources, all else equal, hiding part of the internationalization effect in Brazil, Iran, Malaysia, Thailand and other emerging systems.

In large and fast-growing China, the international proportion of citations drops from 51.6 to 37.7 per cent in 1996-2014. China is exceptional because of the global weight of its output. In every other country in Table 16 except Russia, the international share of inward citations grew. This indicates the secular tendency to internationalization of knowledge. Note that despite the rapid increase in total output in small Singapore and middle sized South Korea, in both of these cases there has been rapid increase in the international proportion of citations to their publications. This suggests that in those systems there has been an exceptional increase in quality as well as the quantity of papers.

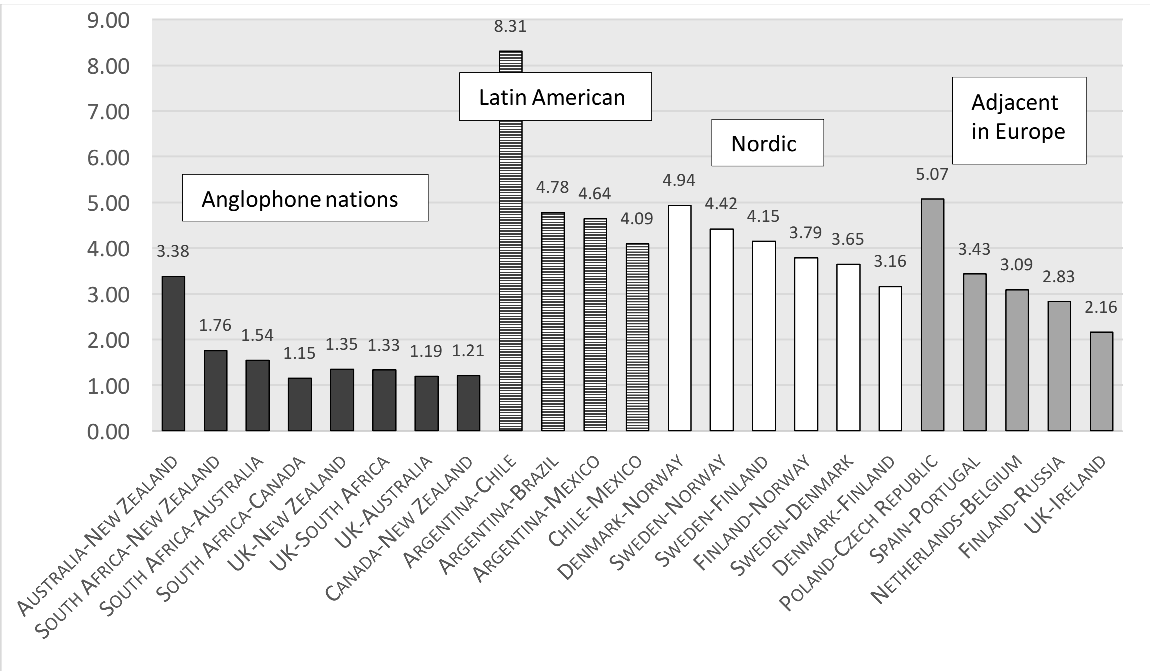
Patterns within the network

Networks may be flat, but they are not always symmetrical. Some partnerships are worked more intensely than others. Lines of influence can be one way or mutual. The line in and out of some countries and WCUs are especially active. The United States is the world's most important single nation for collaboration, the 'largest contributor of partners' (Wagner, et al., 2015, p. 7). United States-based authors appeared in 38.6 per cent of all co-published articles in 2016 (NSB, 2018, Table A5-42) and are directly linked to most countries, and indirectly linked to all countries, in the global network (Wagner, et al., 2015, p. 7). However, in the network setting US leadership is dominant rather than hegemonic. It is not exercised by excluding other countries from accumulating connections in zero-sum fashion. As noted, in networks openness and pluralization coexist with strong and even dominant nodes.

Favoured partners. Within the thickening connections of every nation with other nations, and each WCU with all others, some relationships are especially strong because of cultural similarity, historic links, and sometimes policy and funding drivers. Figures 11 and 12, and Tables 18 and 19, 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 counties' links with all countries; 0.50 indicates weak collaboration intensity and 2.00 indicates unusually strong intensity. The collaborative index is the same for both partners. Note that in nations with modest total published science, small changes in the number of co-authored papers with another country can generate sharp rises and falls in the collaboration index. Larger research countries provide more meaningful trend data.

Figure 11 provides examples of intensive collaboration in 2016 between nations based on historical links and geographical contiguity. Among the English-speaking countries, the intensity of collaboration between Australia and New Zealand (3.38, representing 1977 joint papers in 2016) reflects the fact they are geographic neighbours, as are Canada and the US (1.13, 19,704 papers in 2016, 43.5 per cent of all joint papers involving Canadian authors). Canada was the only Anglophone nation with which US researchers collaborate at above 1.00. The US collaboration index with the UK was 0.77, albeit representing 25,858 papers and 29.5 per cent of joint UK work. The index for collaboration with researchers from Australia was 0.75, meaning 12,127 papers and 28.8 per cent of all joint papers involving Australians. Australia's co-publication with the UK of 8838 in 2016 was less than with the US but the UK-Australia index was higher at 1.19 (NSB, 2018, Tables A5-43 and A5-44).

Figure 11. Selected examples of intensive regional research collaboration in 2016: Rate of international co-authorship in science and engineering papers between named countries in the pair, relative to their overall rate of international co-authorship with all countries
(1.00 = expected rate of collaboration, 2.00 indicates very intensive relationship within network)



Science includes some social science.
Source: Author, drawing on data in NSF (2018), Table A5-43

Figure 11 also shows the intense collaboration between the three Spanish-speaking Latin American nations that have the strongest science systems—Argentina, Chile and Mexico—and between Argentina and its Portuguese speaking neighbor Brazil. Adjacent Chile and Argentina had the phenomenal index of 8.31, though neither are large research nations and this index number represented only 622 joint papers. In total there were 1500 co-publications between the three Spanish speaking countries. This was only one fifth of the number of papers that the three countries between them shared with the United States, indicating how the dominant US sustains a strong role in relation to small science systems even when the collaborative index is low. Another intensive regional collaboration, on a larger scale, is between the four Nordic nations in Figure 11: Denmark, Finland, Norway and Sweden. They share geographical location, historic ties and common social systems; and their universities collaborate in the Association of Nordic University Rectors Conferences (NordForsk, 2018). The six possible permutations between the four nations had collaborative indexes of 3.16-4.54. In total there were 9865 collaborative papers across the region in 2016. To put this regional total in perspective, it was almost three quarters of the 13,662 papers the four Nordic countries between them co-published with the much larger UK science system, and about 60 per cent of what they co-published with US researchers—again underlining the point that large systems play a large role in the network.

Table 18. Intensive research collaborations by United States, China and India in 2016: Rate of international co-authorship in science and engineering papers between named countries, relative to their overall rate of international co-authorship with all countries
(1.00 = expected rate of collaboration, 2.00 = intensive relationship within the global network)

UNITED STATES AND …	
Israel	1.33
South Korea	1.23
China (+)	1.19
Canada	1.13
Taiwan (-)	1.05
Mexico	1.04

CHINA AND …	
Singapore (-)	2.03
Taiwan	1.73
Pakistan (+)	1.23
United States (+)	1.19
Australia	1.15
Japan (-)	1.09

INDIA AND …	
Saudi Arabia (+)	2.59
South Africa (+)	2.28
Malaysia (-)	2.17
South Korea (+)	2.16
Thailand (+)	1.98
Taiwan	1.74
Pakistan	1.60
Hungary (+)	1.50
Turkey (+)	1.26
Czech Republic (+)	1.18
Finland (+)	1.11
Ireland (+)	1.11
Poland (+)	1.11
Egypt (+)	1.08
Russia (+)	1.07
Iran	1.05
New Zealand (+)	1.02

(+) indicates significant *increase* in rate of collaboration since 2006
(-) indicates significant *decrease* in rate of collaboration since 2006

Science includes some social science.
Source: Author, drawing on data in NSB (2018), Table A5-43

The final part of Figure 9 lists various intensive pairings between geographically adjacent systems. Others that could have been listed include Austria-Germany (2.63), Austria-Switzerland (2.51). Switzerland-Germany (2.04), Turkey-Greece (4.11) and Malaysia-Thailand (3.74) (NSB 2018, Tables A5-43 and A5-44). Table 18 lists all collaborative pairings with an index exceeding 1.00 for the two largest science systems, the United States and China, and the growing system in India. Both the US and China had many pairings with below average intensity and a small number above 1.00. US science was focused on neighbours Canada and Mexico, there was a special tie with Israel (1.33, 4533 papers), and intensive relationships with each of South Korea and Taiwan where the US played a great role in capacity building from the 1950s onwards, and in part continues that role in doctoral training, a common source of cross-border publishing. But as The numbers above 1.00 indicate where the US had special priorities, but as noted they do not exhaust the US global role through the collaboration mechanism. For example, the US shared 28.5 per cent of all internationally collaborative papers involving German authors, 25.3 per cent in France, 29.8 per cent in Netherlands, 32.7 per cent in Japan, a high 47.6 per cent in South Korea, 32.0 per cent in India and so on (NSB 2018, Tables A5-43 and A5-44).

Researchers in China had a close relationship with Singapore (2.03, 4413 papers), though this intensity had diminished since 2006 (3.02) There was also a strong scientific collaboration with Taiwan, and a growing link to regional neighbor Pakistan. The collaboration with researchers in Japan declined from 1.51 in 2006 to 1.09 in 2016. The number of Japan-China collaborative papers multiplied by more than two and a half times in that ten years, but maid the huge growth of research in China the relative importance of collaboration with Japanese researchers within Chinese science declined sharply.

Table 19. Intensive research collaborations in and outside Europe, of Germany, Finland and United Kingdom in 2016: Rate of international co-authorship in science and engineering papers between named countries, relative to overall rate of international co-authorship with all countries
(1.00 = expected rate of collaboration, 2.00 indicates very intensive relationship within network)

GERMANY AND …	
Austria (+)	2.63
Switzerland	2.04
Hungary (+)	1.91
Netherlands (+)	1.68
Poland	1.63
Russia	1.56
Greece (+)	1.52
Czech Republic	1.51
Denmark (+)	1.51
Finland (+)	1.44
Sweden (+)	1.38
Belgium (+)	1.35
Ireland (+)	1.30
Italy (+)	1.30
Norway	1.26
Spain	1.19
France	1.16
Portugal	1.08
United Kingdom	1.07
outside Europe	
Israel	1.31
Chile (+)	1.17
Argentina (+)	1.03
Turkey	1.00

UNITED KINGDOM AND …	
Ireland	2.16
Greece	1.74
Netherlands	1.50
Denmark	1.43
Hungary (+)	1.43
Norway	1.40
Finland	1.28
Italy	1.27
Sweden	1.27
Belgium (+)	1.26
Switzerland	1.21
Portugal	1.19
Spain	1.16
Poland (+)	1.12
Germany	1.07
Austria (+)	1.03
France	1.01
outside Europe	
New Zealand	1.35
South Africa	1.33
Australia	1.19
Chile	1.01

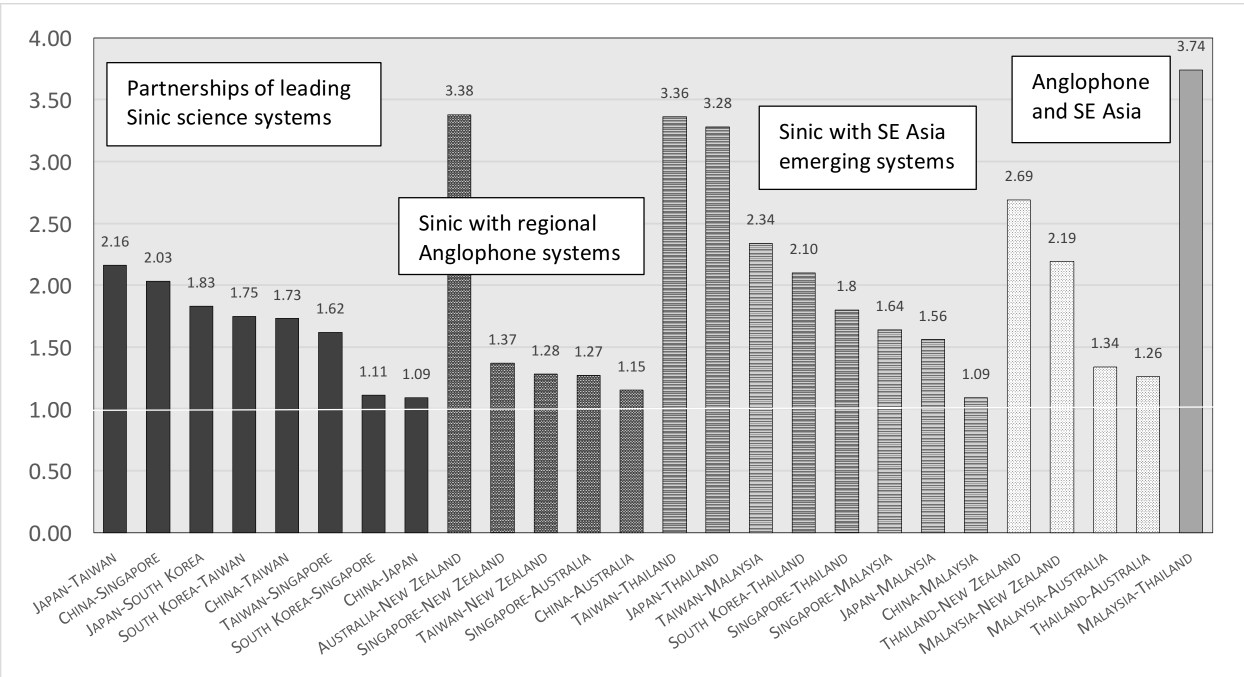
FINLAND AND …	
Sweden	4.15
Norway	3.79
Hungary (+)	3.68
Denmark	3.16
Greece (+)	3.04
Russia (+)	2.83
Ireland (+)	2.79
Poland (+)	2.67
Czech Republic (+)	2.52
Austria (+)	2.18
Netherlands (+)	1.84
Portugal (+)	1.84
Belgium (+)	1.74
Switzerland (+)	1.72
Spain	1.56
Italy (+)	1.53
Germany (+)	1.44
United Kingdom	1.28
France (+)	1.24
outside Europe	
Chile (+)	2.18
Turkey (+)	1.80
Thailand (+)	1.69
Pakistan (+)	1.68
New Zealand (+)	1.65
South Africa (+)	1.59
Mexico (+)	1.56
Iran (+)	1.17
Taiwan (+)	1.11
Israel (+)	1.11
India (+)	1.11
Egypt (+)	1.10
Brazil (+)	1.01
Malaysia (+)	1.00

(+) indicates significant *increase* in rate of collaboration since 2006
(-) indicates significant *decrease* in rate of collaboration since 2006

Science includes some social science
Source: Author, drawing on data in NSB (2018), Table A5-43.

China also sustained a strong link with (Australia 9246 papers in 2016), and with the United. The mutual 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 science network. 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. Despite the standard imagining, the China-US relation in science is by not primarily competitive.

Figure 12. Intensive regional research collaboration in East and Southeast Asia/Pacific in 2016: Rate of international co-authorship in science and engineering papers between named countries in the pair, relative to their overall rate of international co-authorship with all countries
(1.00 = expected rate of collaboration, 2.00 indicates very intensive relationship within network)



Solid dark bars indicate partnerships between the research-intensive East and Southeast Asian systems (China, Japan, South Korea, Taiwan, Singapore); lighter grey indicates emerging Southeast Asia (Malaysia and Thailand). Lined bars indicate partnerships between research-intensive systems and emerging Southeast Asian systems. Hatched bars indicate collaboration with the regional Anglophone systems (Australia and New Zealand).
Science includes some social science.
Omits South Korea- New Zealand (1.03) and South Korea-Malaysia (1.02) for reasons of space.
Source: Author, drawing on data in NSB (2018), Table A5-43.

India’s collaborative publishing as listed in Table 18 is on a smaller scale and more eclectic, with presence in Southeast Asia, the Middle East and parts of Europe, though there was a weak relationship with China in 2016 (0.39, representing 1585 papers). The collaborative index with the United States was only 0.83 in 2016 but because of the size of US research this was India’s largest collaborative relationship in volume terms. The 6759 papers published with American researchers was more than three times the next largest group, the 1839 papers with South Korea (NSB, 2018, Tables A5-43 and A5-44).

Table 19 illustrates the fact that the European science systems have placed each other on high priority and this may have precluded the evolution of more intensive relations elsewhere. Germany and Finland had collaborative indexes above 1.00 in 2016 for *every* European country in the NSB data. In most cases the intensity had increased since 2016, particularly in Finland. The UK had indexes above 1.00 for all named European countries except the Czech Republic and Russia. Germany and the UK had few intensive relationships outside Europe; UK researchers had only one outside Europe and the Anglophone zone, 1222 papers with Chile in 2016 (1.01). Finland had a longer list of collaboration indexes above 1.00, but most of the numbers involved were small, for example 230 joint papers with Iran in 2016 (1.17), and 183 in Thailand (1.69) (NSB, 2018, Tables A5-43 and A5-44).

Table 20. Intensive regional citation patterns in science and engineering in (1) Latin America and (2) Western Europe, selected countries, 2014
(1.00 = world average citation rate. 0.50 is very low citation rate, 2.00 is very high citation rate)

Citing nation:	**Rate research from these nations is cited by the citing nation:**			
	Argentina	Brazil	Chile	Mexico
Argentina	54.11	1.56	3.24	1.47
Brazil	1.80	12.60	1.21	1.10
Chile	2.91	1.02	62.47	1.33
Mexico	1.69	1.14	1.60	27.95

Citing nation:	**Rate research from these nations is cited by the citing nation:**		
	France	Germany	UK
France	7.72	1.23	1.30
Germany	1.07	6.28	1.32
UK	1.00	1.15	6.10

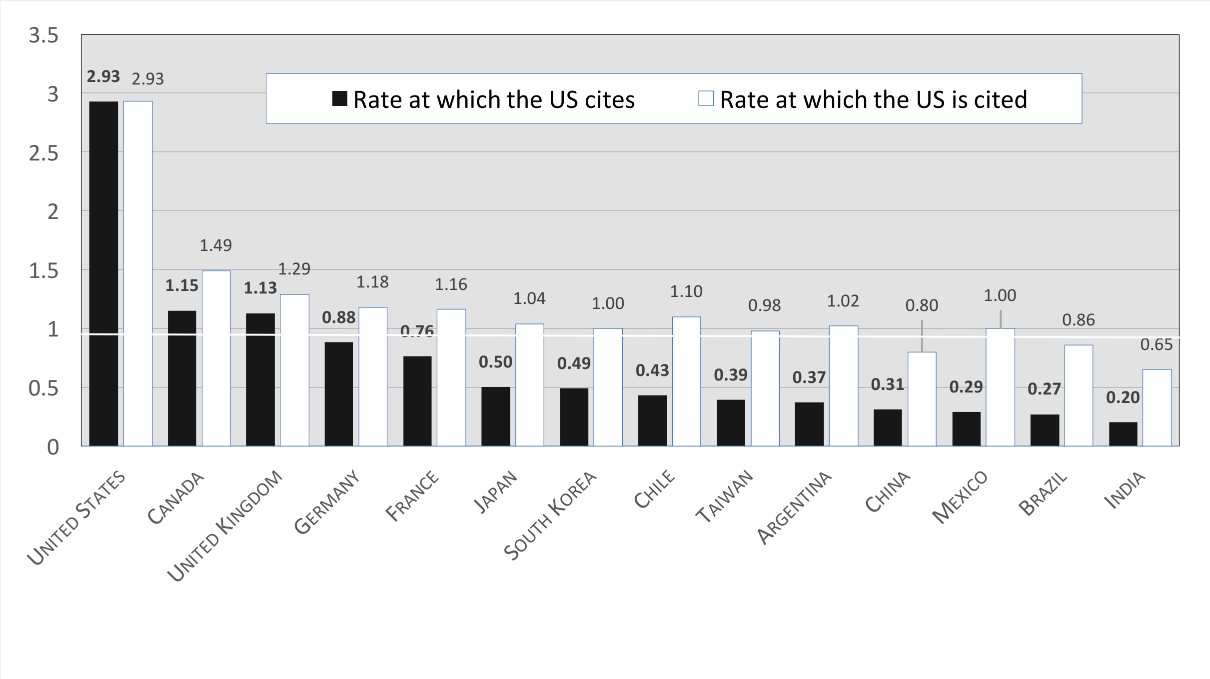
Science includes some social science.
Source: Author, using data from NSB (2018), Table 5-28

Figure 12 looks at the pattern of collaborative linkages in East and Southeast Asia. It shows how researchers in the strong science countries in the Chinese civilizational zone—China, Japan, South Korea, Taiwan and Singapore—network intensively with each other, and also with researchers in the two fast-growing emerging Southeast Asian systems of Malaysia and Thailand. At the same time, the two Anglophone nations in the region, Australia and New Zealand, have developed close collaborations into Malaysia and Thailand and also with their Southeast Asian neighbor Singapore, but may be less focused on East Asia. In the science systems of Malaysia and Thailand the largest regional relationships in volume terms are with Japan and Australia. However, the number of joint papers with Japan and Australia is exceeded by the US in Thailand and UK in Malaysia (NSB, 2018, Tables A5-43 and A5-44).

Who cites who. 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, while 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. Citation data enable the apparent direction of intellectual influence to be mapped. Table 20 foregrounds intensive citation relationships within Latin America and selected pairings in Europe. In the data on the four Latin American countries research relations between Chile and Argentina are again strong, as in the co-publication data in Figure 11, and are essentially reciprocal. Argentine papers cite Chilean researchers at 3.24 and Chileans cite Argentines at 2.91. The table also indicates high priority and near reciprocity in citation relations between France, Germany and the UK. All the cross-border citation rates fall between 1.00 and 1.32. UK researchers are the strongest citation attractors, slightly ahead of those from Germany (NSB, 2018, Table 5-28).

Figure 13 goes directly to patterns of influence. It shows that United States' researchers are cited by researchers from other nations much more than US researchers cite them. Americans often focus on their large strong domestic science system. There is no equivalent in other nations, except in China. However, Americans cite research in China at the low rate of 0.37, below other East Asian nations, whereas researchers in China cite US researchers at 0.80. This suggests that Americans saw the Chinese research published in 2014 as of relatively low quality overall. Researchers in only two countries are cited by US researchers above 1.00, Canada and the United Kingdom. UK researchers come closest to equality of respect, citing US researchers at 1.29 and being cited at 1.13 (NSB, 2018, Table 5-28).

Figure 13. 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
(1.00 = world average citation rate. 0.50 is very low citation rate, 2.00 is very high citation rate)



Science includes some social science.
The expected value of citation is 1.00, but unlike the collaboration index, citation index scores are not symmetric. For example, if country A cites publications by country B 15% more often than expected, that does not mean that country B also cites publications by country A 15% more than expected, as is clear from this graph. In each case, authors from the other nation cite United States' authors at a higher rate than United States' authors cite them.
Source: Author, using data from NSB (2018), Table 5-28

Using national data to describe the science network can be misleading. As Wagner and colleagues (2015) remark, in most countries, at least, WCUs deal freely and directly with each other in matters of science without having to pass through a nation-state filter. National data predisposes the network analysis towards competitive comparison, despite the flat, open and cooperative character of the network. In that respect, the data on the networking behavior of WCUs themselves might be less pejorative. There the nodes in the network appear as unequal but contributing to each other, rather than locked in a zero-sum contest. Still, the data do not specify the balance between cooperation and competition in global science. It is impossible to say what proportion of research collaboration and cross-border citation, or which collaborations and citations, contribute to global common goods.

All that can be stated for certain is that in global science the secular trend is to ever-increasing collaboration, with an ever-increasing number and range of national systems and WCUs, increasing the potential for global common goods. Those common goods can be maximized by identifying, monitoring and broadening the shared global ground, while developing global systems in which diverse contributions are more fully recognized and valued, especially those in languages other than English. Research collaboration between WCUs also 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.

5. Limiting factors

As was noted in section 1, the contribution of WCUs everywhere to common good(s), national and global, is articulated through, and also limited by, two factors. The first factor is the role that WCUs play in relation to social equality/inequality, especially in highly stratified national higher education systems, and in educating internationally mobile students. The second factor is the influence of nation-states on the cross-border potentials of WCUs, in relation to people mobility as well as global cooperation in science.

WCUs and equity

Some WCUs make strenuous efforts to connect to local communities, cities and local regional development. Yet nowhere do the benefits created by WCUs flow equally and everywhere, like classical common goods such as sunshine or public security. By their nature, scientific disciplines and other fields of study are not readily democratised. This does not stop knowledge from functioning as a common good, but it makes it less visible. As well as this natural limitation, there is a social limitation to WCUs as common goods.

The common good of equitable participation is the most celebrated collective objective in higher education. It is central theme in the politics of higher education, in neo-liberal polities such as the UK, social democratic regimes as in the Nordic countries, and state dynastic regimes such as China. Equity in education is a keystone common good, one that enables the production of many other public and private goods. That higher education should offer fair opportunities to young people is part of the social contract (explicit or implicit) between a national higher education system and the population it serves. In most countries, the nation-state is seen to share with higher education institutions the responsibility for maximizing social equity (though in some countries, governments attempt to shift the main burden onto the institutions). The common good function of mass higher education, in providing equitable opportunities, is obvious. But in WCUs, no single policy issue is more problematic than the question of social equity, or fair access.

Within the broad concern about social equity, in most countries the position of WCUs—the most visible, discussed and sought-after universities in every society—is at best ambiguous, at worst highly regressive in relation to the commons. Socially exclusive WCUs raise critical questions about the undermining of educational equity, social equality and solidarity at local/national levels. WCUs are mostly over-subscribed and excluding institutions, which limits their capacity to provide for equity as social inclusion. They have a vested interest in lifting themselves above other higher education institutions, and in fostering high rates of returns for their graduates, though both of these stratify opportunity and value. Almost everywhere, their students are drawn from families that on average are more affluent, and carry more social and cultural capital, than the population as a whole. In many countries inequalities in access are apparent in terms of location or ethnicity as well as family income or parental education (e.g. of many Harper, Patton and Wooden, 2009). Stratified offerings and advantaged users, together, limit the capacity of WCUs to provide for equity in the form of equality of social outcomes. While universities by themselves cannot secure an egalitarian distribution of income, a flat wage structure or the abolition of poverty, education is one factor that determines social allocation and mobility.

Table 21. Rates of entry to UK university tiers, by social background and school background, combined entry data for 1996, 1998, 2000, 2002, 2004 and 2006 (n=36,629 entrants)

	Russell Group universities %	**Other pre-1992 universities** %	**Post-1991 universities** %
All entrants	22	20	58
SOCIAL BACKGROUND			
Higher Professional/Managerial	35	23	42
Lower Professional/Managerial	25	22	53
Routine Non-Manual	20	20	60
Manual	13	17	70
SCHOOL BACKGROUND			
Private	53	24	23
State	20	20	60

Source: Developed from Boliver 2013, p. 350

Science and society. Social access to WCUs matters not only because WCUs facilitate access to professional labour markets and high-income jobs. WCUs are also gateways to science and other forms of powerful knowledge. WCUs are typically elite in both the intellectual and the social sense. The two differentiations are heterogeneous and not essentially linked. Knowledge is not exclusive to particular classes. Yet the two kinds of distinction have come to form a common system underpinning the operation of WCUs. In WCUs each kind of distinction provides favourable conditions for the other. Stellar research output provides the leading WCUs with prestige that makes their credentials more valuable as a target for family investment in education as a private good. Science supports social distinction. Reciprocally, the support of the affluent families who over-populate those

WCUs helps to sustains the flows of public and private money that underpin research: social distinction supports science. Meanwhile, the great majority of other students, many from poorer backgrounds, who are able to enter less tier institutions but not the WCUs, find that the commanding heights of knowledge are as far above them as ever.

Growth and equity. Hence growth in the number and size of WCUs has two meanings. It signifies the augmentation of scientific capacity, and also growth in the number of elite university places. At first glance it might seem that the expansion of participation in a higher education system, with growth in the WCUs along with it, must broaden access to those WCUs. Surely, there are more places in the WCUs and they can draw on a broader pool of potential recruits. However, history shows that growth in participation is rarely associated with a democratization of entry into WCUs. Boliver (2011, 2013) finds that the last forty years of expansion of higher education in the UK failed to secure a more socially representative student body in Russell Group universities, the leading sub-sector in UK higher education, the majority of which are WCUs. Students who are first in their families to participate, or from state schools, tend to concentrate in low tier institutions. Students from high fee independent private schools are strongly concentrated in the top tier universities.

The UK has a highly stratified and competitive education system. However, in almost all countries, places that offer significant positional advantage tend to be captured by students from the affluent families best able to compete; and first-in-family students tend to become concentrated in lower tier institutions (Shavit, Arum and Gamoran, 2007). The study of high participation systems by Cantwell and colleagues (2018) agrees. As systems expand, the number of elite places rarely grows in proportion to the overall expansion of participation. The competition for entry into WCUs is intensified. All else being equal, the WCUs become lifted further above other institutions in social status, and more attractive to potential users, prompting additional family investments in time and money to secure entry. They become more middle-class dominated, not less (Marginson, 2018b). Stratification effects are often magnified when government invests extra resources in WCUs in order to lift their global research performance, for example as in Germany, France, China, South Korea, Japan and Russia, and in the UK through the differential distribution of funds on the basis of research outcomes, as measured in regular Research Excellence Framework assessments. The world-wide flourishing of WCUs is happening at the same time that inequalities of income and wealth are growing in the majority of countries. In high inequality countries, especially the United States, WCUs help to legitimate unprecedented managerial salaries (Piketty, 2014).

National differences. At the same time, the precise implications of WCUs for social equity vary between national systems. First, ideas of equity vary, and this shapes provision. In the Nordic jurisdictions equity in higher education is understood as universal access to high quality provision (Valimaa, 2011). In the Nordic world, Germany and the Netherlands, WCUs are first among equals, and their success does not preclude high quality provision by other universities or second sector institutions. Social competition is less about institutional ‘brands’ and more for access to high status professional fields like medicine and law. There, social inequalities are difficult to eradicate, even in egalitarian Nordic systems, primarily because of the effects of unequal family cultural capital in shaping success (Thomsen, et al., 2013; Valimaa and Muhonen, 2018). In contrast, in English-speaking nations, equity is mostly seen as fair individual access at system level to stratified private economic benefits, within a hierarchical structure of institutions. Lofty WCUs in US and UK tend to reinforce starting social inequalities through a process of ‘cumulative advantage’ (Di Prete and Eirich, 2006), rather than facilitating extensive upward social mobility (Corak, 2012).

Second, countries differ in the extent to which the schools and the non-university institutions sustain an equitable framework of participation and this affects the feeder population from which the WCUs select. Rural disadvantage in school completion, which stratifies access to first degree level, varies markedly. UNESCO’s location parity index compares school completion rates of rural students to their urban counterparts. It varies from 0.42 in Pakistan, 0.47 in China, 0.54 in India and Indonesia and 0.76 in Brazil, to 0.89 in Russia, 0.99 in United Kingdom and 1.04 in Germany (UNESCO, 2016, statistical annex). In some countries, including the US, South Korea and Estonia, the rate of tertiary participation is much higher than the rate of tertiary completion because of drop-out from institutions below the WCUs. This narrows the potential entrants to WCUs. For example, in the US the gross enrolment ratio exceeds 85 per cent but less than half of these students graduate with a degree (UNESCO, 2018a), and non-completion is highly stratified. Low income family students are much more likely to drop out than those from middle class homes (PELL, 2015).

In most countries there is a wide gap between the tertiary education attainment of people in the top and bottom family income quintiles, with few bottom quintile graduates. Nevertheless, Germany and Netherlands have relatively equal outcomes in this domain. In the Netherlands 60 per cent of 25-29 year olds from the top income quintile had four years of tertiary education compared to 40 per cent of 25-29 year olds in the bottom quintile, an exceptional result in world terms (UNESCO, 2016, p. 231). This provides the platform for relatively egalitarian WCUs, though the affluent middle class is still over-represented.

Equitable WCUs? Though this paper is not primarily focused on common goods at national level, the relations between WCUs and their local/national societies affect their role in global common goods. Universities that observe egalitarian and solidaristic norms in local and national society are more likely to fulfil such norms in their global relations.

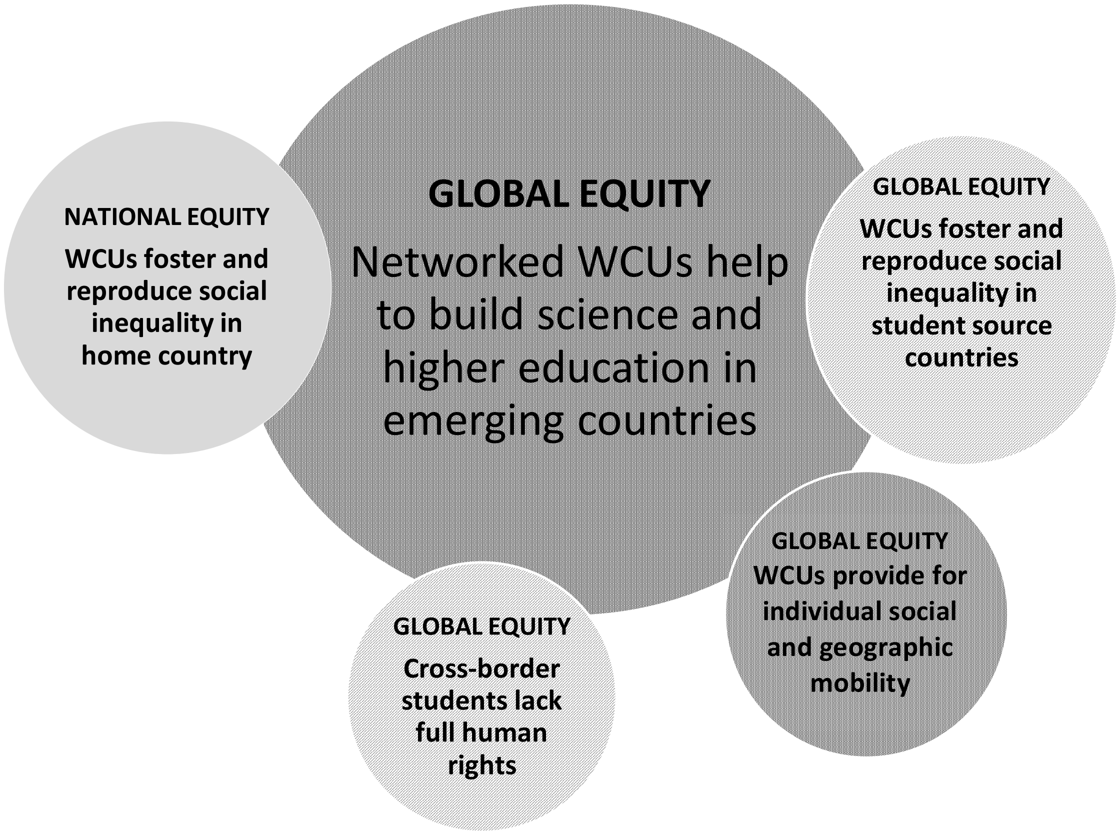
There are two principal methods for achieving more equitable WCUs. The first is difficult to progress and can be attempted only at national system level. That is to configure policy, regulation and funding so as to reduce the extent of stratification between research-intensive universities, and narrow the status gap between the research sector and other higher education institutions. When there is less stratification between universities there is less at stake in social competition between them, and between families for entry. For example, all Dutch research universities appear in university rankings, though none are in the ARWU top 40. The second method can be attempted by individual WCUs as well as state policy and regulation. That is to configure entry policy so as to increase the proportion of students from low-income families and families without prior higher education experience. For example, University of California policy ensures that more than a third of entrants to UC Berkeley and UC Los Angeles are from low income families—despite the fact that in the state of California income inequality is high in world terms (Dirks, 2016; Marginson, 2016b). Social access to WCUs can also be expanded by using a variety of entry points, for example by taking students from institutions other than the academic secondary schools that tend to be dominated by affluent families, more students who are mature aged, and so on.

Global equity. As a political issue, social equity is a creature of the national polity. Beyond the national border there is no standard framework for addressing questions of equity in WCUs. There is no global polity, nor a single global educational population, for fixing benchmarks of representative social composition or affirmative action strategy. Operating in the global space, WCUs, and individual persons, may practice fairness and justice but only on the basis of eclectic, self-proclaimed principles that create no obligations for others. There is no means to devise an agreed rule. The result is that when cross-border activity triggers equity issues within countries, or issues of fairness arise in relations between countries, or in the space between countries, these are not effectively addressed.

Nevertheless, there are at least four distinct equity issues that arise in global higher education. One constitutes a strong argument in favour of globalization. The others, related to student mobility, are more ambiguous. Figure 14 summarizes equity issues in WCUs.

First, fundamentally, collaborative global science advances modernization in emerging countries. It helps to build stable states and functional economies, diffuses technologies, enhances economic and cultural exchange, and ‘thickens’ global civil society. International education also contributes to capacity building in emerging countries (providing brain drain is not uppermost). Above all, global science and education call up those capacities in more countries, as section 4 described. This has implications for more plural relations of power worldwide; and that alone is a strong reason to support the globally networked activities of WCUs in emerging countries. By no means every initiative, project or foreign aid programme is helpful, but, especially in research, where the global science system encourages new players to build autonomous agency, the outcome a win-win for the world as a whole.

Figure 14. WCUs and social equity: National and global issues



Source: Author

The second equity issue related to cross-border students. It is again positive. International higher education provides opportunities for access to higher education, to science and other knowledge, and enables both geographical and social mobility. Arguably, cross-border mobility is in itself a human right. International graduates may have opportunities to enter the workforce in the country of education or to take their degrees to a range of locations. These are substantial gains, though they are not available to everyone.

The third equity issue is the rights and welfare of the 4.4 million cross-border students. This is negative in relation to equity, the downside of the previous point about enhanced mobility. Outside their country of citizenship, cross-border students are not fully protected by its laws and protocols. Nor do they have citizen rights in the nation of education. Compared to resident national citizens, they have incomplete human, civil, economic, social, welfare and political rights. In some countries that provide international education on a commercial basis, cross-border students have consumer protection rights. These are limited (Marginson, 2012). Cross-border students face significant and distinctive difficulties in domains such as legal recognition, access to banking, commercial housing, exploitative work practices, dealing with immigration regulation and so on (Marginson, et al., 2010). This issue is insufficiently researched, though it is sometimes the subject of formal discussions between student source country governments and education country governments.

The final issue is again negative for equity. That is the effect of international education on social stratification in the source countries from which students come. this parallels the stratification effects of WCUs in domestic education. Outside of Europe, where there is much educational traffic between countries, the great bulk of mobile students travel from the emerging countries to developed university systems in the English-speaking world, Europe, Japan and increasingly, China. As noted, many enter WCUs. Most of those students, especially those who pay full cost fees and support their living costs in the country of education, are from families with above average incomes in the home country. Some are from wealthy backgrounds. A complicating factor is that middle income students from, say South Asia, Southeast Asia or Latin America become poorer students in parts of say the US and UK, because of cost of living differences. But the main issue is what happens when already socially advantaged students graduate and return home. At that stage many international graduates leverage their foreign degrees (an opportunity unavailable to most people from their countries) into superior job opportunities and incomes. In this context international education operates as part of a process of elite reproduction; and it may enhance social stratification in the countries concerned. One way to modify such effects is to increase scholarship-based places but it is difficult to effectively target cross-border education scholarships to students from poor families in the student source countries.

There have been no substantial studies of the stratification effects of international education, despite its global scale. This issue also needs further research.

The national and global interface

Globalization and the nation-state are not mutually exclusive. They are inter-dependent. Contemporary globalization dates from the emergence of a new kind of coherent, focused nation-state in the late eighteenth century; beginning with in Prussia, England and France and later followed by the United States and Japan. These were the first 'global competition states' (Cerny, 1997). They saw themselves in world context and locked in continual competition with each other. They watched each other closely and strove by turn to imitate each other, or innovate to gain an advantage, in the military and industrial domains. In the twentieth century this kind of state became dominant (Bayly, 2004). While this kind of state resist the dissolution of its identity into a larger world polity, over time it tends towards convergence with other states. Nation-centred globalization is one of the factors that has shaped the evolution of world higher education and science. Wagner and colleagues remark that the nation was crucial in the evolution of research policy after World War II. The relationship between science and nation became especially strong. Nation-states became the main patrons of research, and science became part of national identities (Wagner, et al., 2015, p. 3). This is part of a longer pattern in which leadership in science was joined to global leadership, passing from France to Germany to Britain and the United States (pp. 11).

However, remark Wagner and colleagues in relation to networked science, 'the current growth of international collaborations appears not to reinforce these patterns and puts into question the relationship between science and the state' (Wagner, et al., 2015, pp. 11-12). In the last three decades the relationship between science and nation-state has shifted. 'We see the growth of international collaboration as decoupling from the goals of national science policy' (Wagner, et al., 2015, p. 3). Nation-centred globalization, in which nation parallel each other inching forward ahead of each other in an endless race, is not the only form of globalization in higher education and science. WCUs are also shaped by world-system globalization, for example in communications and research, which has a dynamic independent from nations and across all of them. This second kind of globalization encourages not just global convergence, but integration into the single system. Its ultimate logic is the dissolution of the nation-state. In science this has already partly happened.

Global science, communications, financial flows and even transport systems in practice can no longer be wholly contained within a single country or blocked at the border. The costs of attempting the blockage are too great. States and WCUs have to position themselves to advantage within these global systems, that they can neither evade nor completely control. Because of global science and their dependence on cross-border people mobility, WCUs are among the most globalized social institutions. And yet—the national dimension still matters. Modern universities were mostly created in the nation-building programmes of states (Scott, 2011) and WCUs cannot be meaningfully separated from the nation-state any more than from society. Universities are governed by national regulation and in most countries are bound to national policy. Most WCU funding is sourced nationally, whether sourced from states, industry or households. Research capacity is quintessentially global, yet it is also determined by the level of government funding for R&D. National and local institutional contexts articulate global flows and relationships. The effects of globalization vary by country, and also by higher education institution. Individual WCUs have a varying capacity to themselves affect global relations and global common goods. But at the same time, in each country the prevailing political culture governs the political economy of higher education, including the degree of university autonomy in both financial matters and institutional policy (Carnoy, et al., 2013; Marginson, 2016c, p. 119ff).

What then is the resolution of this conundrum—the nation remains a vital influence in WCUs and yet there is global science? The answer is that the nation is stronger in some areas than others. It is strongest where it can exercise a controlling influence, for example in regulation of immigration and other aspects of people movement, where it has both legitimacy and practical power. It is weaker in relation to science, and the flow of messages; and any matters particular to the inner life of WCUs it is partly constrained. In all higher education systems, in normal times, research universities exercise significant autonomy in matters of education, scholarship and science. The leading WCUs have the most freedom. Perhaps higher education institutions are best understood as semi-independent institutions that are irretrievably tied to the state—and WCUs are best understood as semi-independent institutions that are irretrievably tied to both the state and global science. As this formula suggests, there is a permanent and ongoing potential for national/global tensions.

Problems of economic globalization. Because higher education is engaged at many points with its larger setting, the national/global interface in WCUs is affected by national/global tensions in the political economy. There, economic globalization has some ground. In the last decade multinational profits declined by 25 per cent, partly because of competition from more nuanced local firms. The share of exports accounted for by cross-border supply chains increased remarkably between 1995 and 2007, reaching 60 per cent, and then stagnated. Flows of foreign direct investment had declined sharply (The Economist, 2017). There are few efficiency gains to be made from the further lowering of trade barriers; while the number of losers generated by liberalization, like American workers displaced by offshoring—has increased (Rodrick, 2017, pp 5-7, p. 27). US workers lack European social protections, and 'financial globalization appears to have complemented trade in exerting downwards pressure on the labor share of income (pp. 18-19).

This in turn has generated political pushback. Popular movements use differing narratives of left and right to explain the negative distributional outcomes. While the political left creates an 'income/social class cleavage', the populist right has created 'an ethno-national cultural cleavage' (p. 24) in which non-white migrants and urban cultural cosmopolitans are the beneficiaries of globalization who secured their gains unfairly at the expense of displaced white Americans. Hence 'even when the underlying shock is fundamentally economic the political manifestations can be cultural and nativist' (p. 25).

WCUs are constantly involved in cross-border flows of English-language knowledge, ideas, systems, people and capital; and by global comparison and ranking, visioning and strategy-making (Hazelkorn, 2015). However, while some higher education systems earn significant revenues from international students, overall WCUs are more affected by cultural-scientific globalization and cross-broader people mobility than by the economic aspects. They are relatively free of the direct tensions associated with trade and financial globalization. Nevertheless, as noted in section 2 universities are open to populist challenge, especially when it entails the rejection of all things cosmopolitan and global. WCUs have been directly affected by the demonizing of migrants in some countries, as will be discussed. Science—the most globalized aspect—has been less of a target, except in the United States.

It should be noted that the limits to economic globalization, and the populist backlash, are primarily on a regional not global scale. They are phenomena of Europe and North America rather than the world as a whole. WCUs in East Asia remain largely unaffected.

Research. Though the science system is an unquestionable benefit to the world as a whole, WCUs are seen by governments as instruments of competition with other nations. This, more than scientific curiosity, drives the accelerated investment in WCUs. Likewise much discussion about research imagines the rise of China and other emerging nations in a zero-sum framework, as if the growth of science outside the once dominant countries in North America, Europe and Japan must mean those countries are 'declining'. At present such sensibilities are felt strongly in the United States and Japan. In short, science (like most public goods) can become annexed as an instrument of state. Yet that same science is pursued by universities, and while they defer to states, they are also free global actors.

In their study of the global science network Wagner and colleagues (2015) find that national science communities vary in the extent to which they have become absorbed into the global system. Generally, 'the more internationally connected the scientific workforce of a nation, the more likely it is that the national agenda is being set de facto at the global level' (p. 9). They compare nations on the basis of whether their domestic distribution of science publications is more predictive of the international distribution of their activity, or vice versa. The former are seen as nationally driven, the latter as globally driven. Nations that appear internationally driven include the United States, Canada, China, Brazil, Chile, Russia, France, Germany and the majority of EU countries. Nations that are nationally driven include the United Kingdom, the Nordic countries, India, Iran, Saudi Arabia, Japan and Australia. They find that two types of national science system are domestically driven. One is those that are 'geographically isolated'; they instance Japan and Australia. the other is nations with 'a strong national identity and a history of science tied to national development such as the UK and the Scandinavian countries', which, even though they participate in European research programmes, 'still maintain their own more strongly organized national institutions and policies'. However, the global group is larger:

> In summary, the international and national networks may be shaping each other in a process of co-evolution between the national institutional structure and the global network. The relative influences of national and international networks appear to vary among nations. Globalization and internationalization can first be considered as a tendency, but in more than half of the countries, the international network has become the better predictor of the national participation at the global level than vice versa. In other cases, national patterns of collaboration still prevail. (Wagner, et al., 2015, p. 11).
>
> .. international cooperation is particularly advantageous for less advanced countries; network participation should enhance that advantage because it enables efficient collective search… The active and robust global network is proof of its own usefulness. Researchers gain enough benefit from it that they are willing to extend the extra time and effort to maintain long-distance communications. Should capacity continue to grow in more places around the globe, one can expect to see more 'nodes' join the network. The global network

> is arguably now a more stable system that serves as a source of vitality and direction to R&D at all lower levels… The global network presents opportunities for science policy-makers to seek efficiencies that were not available when a few nations dominated science. With improved scanning of research and more effective communications, it may be possible to leverage foreign research, data, equipment, and know-how … it may be possible to ask grant seekers to identify possibilities for efficiency gains through international collaboration, and then provide the financial and policy supports to integrate knowledge from abroad.
>
> This dynamic system, operating orthogonally to national systems, is increasingly difficult to influence and even less amenable to governance as it grows. This does not mean that nations must build an international governance mechanism, but that they must learn to manage and benefit from a network. Networks operate by reciprocity, exchange, incentives, trust, and openness… (Wagner, et al., 2015, p. 12).

Because 'the growth of science is occurring to a disproportionate extent at the global level', argue the authors, this 'may be attracting more prominent scholars to work together across national borders, and drawing way top thinkers from focusing on local needs… Distributed research that favours the use of the most efficient producer may enhance overall outcomes' but result in gaps in capacity at local levels (Wagner, et al., 2015, p. 11).

Mobility. There is a latent and unresolvable tension between the right of people to cross any national border (free global mobility is a global common good) and the right of nation-states and national populations to control access to the territory to which they claim legal ownership. There is an inherent conflict between the global common good of free mobility and the national common good of national security; a conflict which becomes obvious during periods of popular resistance to migration, as in the last decade in UK. WCUs have a vested interest in free people movement because many of them are dependent on flows of international students and especially, non-citizen doctoral students and faculty. For WCUs the tension—which is never latent--is between free talent recruitment and migration regulation, including visa availability, processing and conditions, and length of stay.

One example that could be cited is restrictive and often hostile policies on migration in the United States, under the Trump administration, followed by declining international student enrolments. The example that will be discussed instead is the UK. There, migration resistance has been associated with both the decision to leave the European Union, which threatens existing non UK EU citizen staff in WCUs and inhibits future recruitment of faculty and doctoral students, and also restrictions on international student recruitment. These are significant effects in relation to mobility in UK higher education and science. Note however that migration resistance in the UK electorate has been primarily driven not by international students (there is no evidence of public opposition to international students), or refugees as in many European countries, but labour migration from Eastern Europe. This was a key driver of the June 2016 referendum decision on Brexit. EU membership is a target of most of those opposed to migration. However, international education has been collateral damage.

In 2016-17, 17.4 per cent (35,920) of all faculty employed in UK universities were from non-UK EU countries. The proportions were higher at several UK WCUs, including 27.0 per cent at London School of Economics, 24.9 per cent at Imperial College and 21.4 per cent at University College London (HESA, 2018). Recruitment of high quality EU-citizen staff has been facilitated by the free movement of persons within the EU, which allows both free entry and indefinite residence. After the UK leaves the EU, citizens from its member countries will be treated in the same manner of those from non-EU countries. This will reduce the pool of available talent from Europe. Brexit has also encouraged many existing EU-citizen faculty to return to continental Europe, though numbers are not available.

In commercializing international education in 1979 the UK created what became a major export industry. In 2017 Oxford Economics estimated the full direct and indirect economic benefits of international students were £25.8 billion in 2014-15. The direct export earnings were £10.8 billion (UUK, 2017). Until recently, UK enrolled the world's second largest number of on-shore international students, after the US. However, there has been little growth in on-shore international student numbers in the last five years. A number of policy decisions, all worsening national/global tensions, have constrained education exports.

First, in the face of migration resistance, in the last half decade the UK government has frequently promised major cuts to net migration. International students are included in the net migration count, although they are only temporary migrants. While there was no substantial reduction in net migration until 2017, in the light of the government's commitment it was obliged to hold international education in a no growth position. This can be achieved by limiting the number of student visas granted to educational institutions, slowing the processing of visas and increasing the number of refusals. All these mechanisms have been used. Second, in 2016 the government announced that there would be a large-scale cut to non-EU international student numbers of 30-40 per cent. This never materialized, but no doubt the announcement contributed to holding down both demand and supply. Third, the government has run a restrictive policy on post-study work visas, which has particularly inhibited demand for UK international education from South Asia.

Globally active WCUs in the UK have been unable to secure a liberalization of UK regulation of international education. This not only points to the strength of the nation-state in the domain of people mobility, it shows that the national/global tensions are so potent as to trump economic rationality. This is true of Brexit as well as education exports. This environment challenges WCUs to find ways both round and through the national polity.

6. Conclusion

A primary objective of this paper has been to foreground the actual and the potential contributions of World-Class Universities to common goods, especially global common goods. Analyses that focus solely on the private individual benefits of higher education, without regard for the collective and common goods, are highly misleading. The main empirical treatment of common goods in this paper has been in relation to the collaborative global research system, with some focus on cross-border people mobility affecting WCUs. Science and the inter-dependent mobility of messages and people are the key aspects of globalization in the WCU sector and also the areas where the national/global fault-line falls. Nation-states have the tools to control mobility but find it politically difficult to restrict. They do not have the tools to control global research and information, outside the domain of military-related research, because of the public good nature of knowledge. The science system evolves according its own logic. It is increasingly detached from nation-states.

Looking through a solely national lens, the cross-border activity of WCUs may seem marginal. Yet global science, global communications and people 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 global space they are global civil society actors with less constraints on them than at home. In the open global dimension of action, the 'commonness' of WCUs is more developed.

There are limits to what networked WCUs can achieve. They are embedded in separated national contexts as well as global science. They lack the machinery and authority of states. All the same, precisely because there is no global state and the ontology is open, their achievements can be remarkable. Whereas most WCUs over-represent the affluent middle class at home, locked into a cycle of elite reproduction that stymies their common good potential, offshore it can be different. A principal aspect of the flat global science network is its openness to new players and the stimulus it gives to building universities and science capacity in emerging countries, in a win-win framework, a powerful example of the common good norms of equality, solidarity and the broad building of human agency.

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 the parties, provided that relations are conducted on the basis of equality of respect. There are downsides of globalization in the WCU sector, but less than in other sectors. Brain drain, and the tendency to marginalize non-English language knowledge, are the most serious problems. Arguably, the discipline-basis of collaboration is lopsided. The physical sciences STEM disciplines are best served. Yet the humanities and social sciences have a crucial role in building cross-country understanding. In the absence of a global state or regulatory framework, issues of under-production and under-funding of global common goods cannot be fully addressed. Who funds global common goods? Should countries free ride on other's research? Is it sufficient to fund global science as a spillover from the competitive funding of national science budgets, and are there gaps as a result? Should emerging countries be compensated for brain drain of their talent? In a more sophisticated global political setting these issues would be live.

National/global tensions pose growing challenges for WCUs. The obvious problems are in relation to people mobility, especially in the United States and United Kingdom, and in relation to free information flow in China, but local political imperatives must also be more effectively addressed. Many WCUs need to reach out with more vigour to their surrounding communities, cities and regions, giving them real agency in the university's affairs, not slick marketing. WCUs need to become better at popularizing science and collaborative research, and turning global embeddedness into a local asset. Social access can be broadened by bringing in more high-scoring students from low income families in a quota basis (as at the University of California), by providing more diverse routes of entry, and by making stronger partnerships and articulations with non-WCU institutions. WCUs could take a larger responsibility for the functioning of the higher education system as a whole. A stronger networked local/national engagement, complementing engagement in the global science network, can helps the global multiversity to balance its local, national and global missions.

The challenge is then to turn towards to the local, without losing the sense of the global. A global perspective is not separated from or opposed to the different national perspectives. Rather, it needs to combine national visions in a multi-positional analysis (Sen, 1992). Collaborative teams working in many fields of science are able to achieve a global perspective. That has also been this paper's goal: to enable observers to see the global higher education and research space from all sides, without privileging any. If the paper has advanced a global perspective position in higher education studies, it has been successful.

Notes

[1] This paper defines ‘World-Class University’ or ‘WCU’ not in relative terms (e.g. ranked in a top 100 or top 500 listing) but in absolute terms. An ordinal definition based on listings such as 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. For example, as a result of the worldwide growth of science, in the last decade more research-intensive universities have reached each threshold level of total paper output, but by definition the size of the top 500 group cannot expand. The better approach is to use an arbitrary cardinal indicator based on transparent material indicators. For example, one simple indicator of a World-Class University is production of 1000 published, papers over the previous four years, as measured in the Leiden University (2018) ranking. Leiden draws on the Web of Science database produced by Clarivate Analytics. There were 903 such universities as at the end of 2015, based on paper output in the 2012-2015 period. An indicator based on an output of 250 papers per year or more ought to capture all universities that have comprehensive global research activity. It is not a perfect indicator of comprehensive multi-disciplinary research-intensive universities, the type normally imagined in WCU tables, because the 1000 papers benchmark also takes in specialist institutions that work only in a narrow discipline range, and multi-disciplinary universities whose global research strength is likewise highly specialised.

[2] The UNESCO term ‘tertiary education’ is identical to the term ‘higher education’ in only some national systems. ‘Tertiary education’ refers to programme rather than institution, in contrast with some national nomenclature, 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). As is discussed later in the text, ISCED level 5 also includes some short-cycle vocational programmes, though the inclusion of post-school vocational education and training is not fully comprehensive, and has varied by system and over time (UNESCO, 2018b). At national level, in many countries, all ISCED Level 5-8 activity is classified ‘higher education’ but in others this term is confined to Levels 6-8 only, or to activity in designated institutions. The United States is in the last category though in practice nearly all ISCED 5 activity is there included as higher education. For further discussion see Cantwell, et al., 2018, chapter 1).

[3] In *Higher Learning Greater Good* (2009) McMahon, using the economic framework, draws together studies that attempt to measure economic public goods in higher education. He finds that individual non-market benefits captured solely by individuals, such as better health and longevity for graduate and family, average US $38,020 per graduate per year, which is more than the individual earnings benefits ($31,174 per year). What he calls the ‘direct social externalities’ of higher education, such as higher education’s contribution to cohesive and secure environments, civic institutions, cultural tolerance and enhanced democracy, average at $27,726 per graduate per year. In addition, there are the ‘indirect social benefits’, meaning the contribution of direct social benefits to the value generated in private earnings and

private non-market benefits. When this indirect element is included economic externalities, public goods, are 52 per cent of all the benefits of higher education.

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