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Convergence in science
Growth and structure of worldwide scientific output, 1993 - 2008

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Abstract

In this paper, we examine if the globalisation of science is accompanied by convergence in the level and structure of scientific output. We use Web of Science data on the scientific output of c. 200 countries for 1993, 2000, and 2008, distinguished by subject area. We found evidence of absolute and conditional β-convergence and σ-convergence in levels of scientific output, particularly after 2000. The per capita scientific output of smaller countries grows faster than that of larger countries. In addition, all countries show a decrease in the overall degree of specialisation. The national science portfolios of most of the world's countries are becoming increasingly similar. This convergence of portfolios occurs in convergence clubs rather than as a global process. The scientific *output* of nations may follow a common growth trajectory, but there is no common development trajectory for science *portfolios*. Exploratory factor analysis shows that the world's science systems cluster into nine discrete convergence clubs and two meta-clubs – 'North' and 'South' – , each with their own discrete specialisation pattern and structural characteristics. The world remains divided. Small countries are slowly catching up, but large science systems continue to dominate global science. Worldwide science appears to have a stable structure. Most countries remain within their convergence club or shift to comparable clubs. Since 1993, few countries have managed to move from 'North' to 'South'. These countries are swiftly moving up the rankings.

Keywords: convergence; science; globalisation; specialisation; comparative advantage

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1. Introduction

Many view science as an outstanding example of globalisation. The dynamics of scientific research is global in nature, especially in such fields as high-energy physics and climatology. Science has become a global community in which researchers produce for a worldwide commons, or, as Leclerc and Gagne (1994, pp. 17-18) suggest, "a vast single market for the exchange of research products". Scientists increasingly collaborate internationally (Wagner & Leydesdorff, 2005; 2007), especially in big science but also in other fields (Georghiou 1998). They build social networks that are bound by the limits of their specialisation rather than by national borders (cf. Murray, 2004). At the same time, globalisation does not appear to have brought the science systems of the world much closer together. There remain vast differences in S&T performance among the world's nations. As science and technology represent a competitive advantage, it is of vital importance for governments to protect national interests (Archibugi & Michie, 1997) Moreover, countries are different in terms of structural characteristics and initial conditions, which affects their performance (Castellacci & Archibugi, 2008). This provides a good reason not to expect globalisation to produce too much convergence.

In this paper, we examine to what extent the globalisation of science is accompanied by convergence in the level and structure of scientific output. In section 2 we develop the theoretical reasons for convergence and divergence. Using scientific output data for c. 200 countries in 1993, 2000, and 2008 (explained in section 3), we examine if levels of scientific output are growing closer together. Are small countries growing faster than large countries (section 4)? Structural convergence can mean two different things. We first study whether countries converge in terms of the degree of specialisation (section 5). Next, we investigate whether countries are converging towards similar specialisation profiles. Or, to phrase it differently, are national science portfolios converging towards a global agenda (section 6)? In section 7, we put the results in perspective. We draw conclusions and discuss their implications in section 8.

2. Agenda setting, resource allocation and convergence in science

Society invests in knowledge for various reasons: knowledge is inherently valuable as a cultural asset, science is expected to produce major long-term benefits, and science contributes to innovation, providing nations with a competitive advantage. The allocation of resources for science calls for a dual assessment of opportunity costs.[1] First, in the allocation of scarce (public) resources – the expression of the social contract between science and society (Demeritt, 2000; Gibbons et al., 1994) – the relevant choice is one between investing

[1] An assessment of opportunity costs in decision making involves marginal rather than absolute costs, focusing on the allocation of additional resources or a shift of resources from one opportunity to another (e.g. from education to science; from fundamental science to applied science).

in science, with its uncertain, intangible returns and long timeframe, and investing in more immediate and tangible opportunities, such as health care, education, or transport infrastructure. Levels of total research output tell us something about the willingness of societies to invest in science. Second, within the science system, resources are allocated to institutions and specialisations through a variety of channels, such as block grants to universities, organisational allocation mechanisms, competitive funding programmes, investments in large-scale research facilities, transdisciplinary research programmes, and so on (Auranen & Nieminen, 2010). At this level, opportunity costs refer to the scientific and social promises of different research fields, and the choice between investing in infrastructures for future research and expenditure on current research (see also Bonaccorsi, 2008). The process of distribution is reflected in the composition of national scientific output.

Agenda setting in science can be understood as a form of portfolio management. However, the term management presumes a much higher degree of conscious, rational decision making than actually occurs. Agenda setting involves a multitude of actors at various levels in the science system, from the individual researcher in his or her niche, to universities and institutes with a multifaceted mission, and research councils, science foundations, and government ministries that make policy and set priorities. We can model scientific specialisation patterns as the outcome of a social contract between science and society, but there may be many social contracts between many different principals and agents (Slaughter & Rhoades, 2005). This implies that national or global research agendas are emerging from the interactions between a multitude of heterogeneous actors, with a wide range of specialties and private research agendas, located in all sectors and at all levels of the science system. Agenda setting is a complex adaptive process. When we look at national patterns of specialisation, we see the emergent outcome of that process.

In a complex system, outcomes depend on the rules that drive the behaviour of individual agents and the interactions between those agents. Individual researchers look for opportunities to achieve priority and build a reputation (Dasgupta & David, 1994; Stephan, 1996; Whitley, 2000), which requires a careful selection of specialties. Priority determination and reputation building necessitate interaction. Researchers respond to agenda setting in their cognitive and institutional environment, moving into or out of niches (Horlings & Gurney, 2012) depending on opportunities provided by, for example, priority setting in national funding programmes or the global rise of highly dynamic fields such as nanotechnology.
Any decision on the part of an individual scientist, a research group, a department, faculty, organisation or government to focus on a particular scientific specialty, calls for a strategy to mobilise resources. Since resources are by definition scarce, mobilising resources inevitably involves competition. Researchers collaborate to gain access to expertise, research facilities and databases (Melin, 2000); groups, institutions and firms try to attract star scientists (Cross & Thomas, 2008); actors from science and industry build social networks and consortia to grasp a share of large investment programmes (e.g. the EU Framework Programme); and so on.

In theory, the range of possible specialisation patterns is infinite. We might assume that autonomous researchers make independent decisions, driven by their curiosity and creativity, and that the institutional and financial dynamics of agenda setting are entirely national. The result would be a unique specialisation pattern for every country. However, in most disciplines scientific discourse is global and international scientific collaboration is on the rise. Collaboration reflects similarities in specialisation as well as geographic and cultural proximity (Calderini & Scellato, 2005; Guellec & van Pottelsberghe de la Potterie, 2001). Individual researchers may have local autonomy in setting their agenda. But if they are to gather scholarly reputation, their autonomy is bounded: they must latch onto existing, worldwide research agendas (Whitley, 2000). Given that science and innovation are highly competitive arenas, there will be global dynamics underlying national and individual decision making. At a higher level, national and regional governments, universities, and industries shape their research agendas in constant interaction with counterparts in other countries. Scientific specialisation is directly relevant to attaining a strong position in science-based industries (Laursen & Salter, 2005). This means that national research agendas are constructed both autonomously – by individual actors within a national system, guided in part and to varying extents by national policy – and interdependently – through global interaction between researchers, institutions, and science systems.

The salient features of globalisation, most notably the steady increase in international scientific collaboration, work in favour of an increasing similarity in scientific portfolios. Collaboration aligns research agendas. Large funding programmes, such as the EU Framework Programmes and collaborative infrastructures like CERN and ARGO, provide smaller countries the opportunity to enter more resource-intensive research areas. Consequently, we expect that there will be a large degree of similarity in national specialisation patterns. Similar nations make similar 'autonomous' choices, and this may result in the convergence of national scientific portfolios.

Our conceptual framework results in four questions on convergence. (1) Is there convergence in levels of scientific output? The simple approach to this question is to ask whether small science systems grow faster than large systems and if international differences in output per capita have decreased. (2) Is there convergence in the degree of specialization of national scientific output? (3) Is there convergence in specialization patterns or profiles between countries? (4) If growth is not evenly distributed and the scientific portfolios of countries do not converge, what different growth and specialization patterns can be distinguished? Does worldwide scientific output converge towards a global macrostructure or do we find different convergence clubs?[2]

[2] This could be analogous to the technology clubs with considerable differences in innovative capability and levels of technological infrastructure and human skills (Castellacci and Archibugi (2008).

3. Data and methods

Our analysis is based on publication data extracted from the five citation databases of the Web of Science (Science Citation Index Expanded, Social Sciences Citation Index, Arts & Humanities Citation Index, Conference Proceedings Citation Index-Science, and Conference Proceedings Citation Index-Social Science & Humanities). For every country, the total set of publications was extracted by searching the Web of Science for all publications in one benchmark year, analysing the distribution of the results across countries, and selecting the country in question. Each country's output was classified into the 248 subject areas of the Web of Science, using its online analysis tool. In doing so, we collected a dataset for the entire world in 1993, 2000 and 2008.[3]

Our search method does not cover total output to the last publication and by using a single source we subject our analysis to the biases inherent to that source. On the other hand, Meho and Sugimoto (2009) compared the Web of Science with Scopus and found that on the level of entire countries and research domains, the results are very similar. Also, Wagner and Wong (2012) find that the Science Citation Index Expanded covers high-quality research from the BRIC countries (Brazil, Russia, India, and China) about as well as that from advanced countries.

For the purpose of our analysis it is not necessary for the dataset to cover all output, merely that it be balanced and representative. The representativeness of the data is given by the scale and scope of the Web of Science. Balance does require an adjustment: we exclude the social science and humanities. A tentative test of the international distribution of output suggests an Anglo-Saxon bias in such areas as literature and arts. More significant, however, is that the intensive efforts of Thomson Reuters to expand the Web of Science's coverage of the social sciences and humanities create the possibility of a statistical artefact in the results: we might be measuring database expansion rather than real changes in science over time. The dataset consequently covers 170 subject areas.

Our search method produces two kinds of double counting. We double count the output of different nations by assigning a full count to papers produced in international collaboration. World output is consequently overestimated. The result does provide a good indication of the number of instances a researcher from a country was involved in the production of scientific output. As such, output as we define it is a proxy for resource allocation to and within science.

We also double count the output in different subject areas. This will tend to inflate output in highly multidisciplinary research areas at the expense (in relative terms) of monodisciplinary areas. Unless there is a strong national or regional bias towards highly multidisciplinary research, we may assume that subject area inflation has an equal effect on all countries and that national output by subject area provides a good account of national resource allocation.

[3] We tested the annual number of hits for countries sensitive to changes around 1990, such as in Germany, Yugoslavia en the former Soviet Union. By 1993, political turmoil appeared to have ended and the Web of Science had adjusted to the new political boundaries.

We have borrowed methods from two broad methodological traditions. First, there is a rich literature on specialisation in technology and international trade. Various authors have developed specialisation indices and comparative measures for the similarity of compositional data. The second methodological stream concerns comparative studies of (economic) growth and structure. Methods are explained in more detail where they are used.

4. Growth

4.1. *β-convergence and σ-convergence*

Convergence in terms of growth implies that smaller science systems grow faster than larger systems and that the dispersion in levels of scientific output per capita declines. Macroeconomic analysis provides instruments for the study of convergence. Barro and Sala-i-Martin (Barro & Sala-i-Martin, 1995; Sala-i-Martin, 1996) distinguish between two types of convergence: β-convergence occurs when poor economies tend to grow faster than rich economies, while σ-convergence indicates that the dispersion of levels of real per capita GDP tends to decrease over time. β-convergence and σ-convergence are related. σ-convergence implies growth differentials, which means that β-convergence tends to generate σ-convergence. However, β-convergence is necessary but not sufficient for σ-convergence: catch-up growth may be local and convergence may occur within clubs rather than as a global process.

We measure growth in terms of per capita scientific output. Using the method of Barro and Sala-i-Martin gives

$$\phi_{t,t+T} = \alpha + \beta \log(y_t) + \varepsilon_{t'} \qquad (1)$$

where $\varphi_{t,t+T}$ is the annual growth rate of national per capita scientific output – defined as the difference between $log(y_{t+T})$ and $log(y_t)$, divided by T – and $log(y_t)$ is per capita scientific output at time t. If β is lower than zero, there is β-convergence: higher initial levels of per capita scientific output negatively affect rates of growth.

σ-convergence can be interpreted as a decrease in differences in per capita scientific output, and occurs if:

$$\sigma_{t+T} < \sigma_t \qquad (2)$$

where σ_t and σ_{t+T} are the standard deviations of $log(y_t)$ at times t and $t+T$. We have substituted the standard deviation with the coefficient of variation – the ratio between the standard deviation and the mean – to account for changes in mean per capita scientific output over time. If the mean increases and the standard deviation remains the same, then there is convergence.

The results are shown in Tables 1 and 2. There appears to have been neither convergence nor divergence in 1993-2000. The results do clearly show β-convergence in 2000-2008: smaller science systems grow faster than larger science systems. The test for σ-convergence shows divergence in 1993-2000. After 2000, the dispersion of output levels declined somewhat, although not down to 1993 levels. Over the entire period of observation, dispersion increased. In short, the results for σ-convergence concur with those for β-convergence.

Table 1. β-convergence in worldwide science, 1993-2008

	1993-2000	2000-2008	1993-2008
β, per capita output (log)	.004	-.004**	-.000*
	(.129)	(.016)	(.086)
N	181	190	182

Sources: Population from the United Nations Common Database (UNCDB). Scientific output from the Web of Science. p-values between brackets.

Table 2. σ-convergence in worldwide science, 1993-2008

	1993	2000	2008
coefficient of variation, per capita output (log)	.608	.599	.525
N	182	191	192

Sources: Population from the United Nations Common Database (UNCDB). Scientific output from the Web of Science. Output per million inhabitants.

Thus far we have looked for *absolute* convergence, which occurs when there is an inverse relation between growth rates of scientific output and initial output levels. It is fairly obvious that output growth is the result of a more complex process involving a wider set of determinants. We should also look for *conditional* convergence. Is there still a significant inverse relation between scientific output growth and initial output levels when controlling for intermediary variables?

It is not our aim to provide a complete explanation for the growth of scientific output. We merely want to know whether, after controlling for a reasonable set of potential determinants and using the best available data, we still find convergence. Our tests boil down to three models: (1) a resource-based view on national scientific performance, using per capita GDP and population; (2) a knowledge production function based on GERD and the number of researchers[4]; and (3) S&T capacity using per capita GDP, the number of researchers, and gross tertiary enrolment.[5] Different combinations of determinants have been tested to establish their marginal impact on the coefficient of the initial output level. Table 3 presents the main results.

For 1993-2000, our models confirm the absence of conditional β-convergence (Table 3). The coefficients for the initial level of output are not significant. For 2000-2008, all models indicate

[4] The total number of researchers in a country includes researchers in the social sciences and humanities (SSH). However, we exclude SSH from output. We assume that this does not affect the results presented in table 3.
[5] Data taken from the United Nations Common Database (UNCDB) and UNESCO Institute for Statistics Data Centre. Data availability for the intermediate variables, such as the number of researchers per million inhabitants, appears to be biased towards more developed countries.

that there was conditional β-convergence. After controlling for additional explanatory variables, the coefficient for initial output levels remains strong and negative.[6] This confirms our initial findings.

Table 3. Test results for conditional β-convergence

	1993-2000		2000-2008		
	resource-based	knowledge production function	resource-based	knowledge production function	S&T capacity
constant	.053** (2.606)	.091** (2.513)	.095*** (5.964)	.124*** (4.141)	.114*** (4.125)
initial level of per capita scientific output	-.002 (-.676)	-.001 (-.192)	-.006** (-2.595)	-.010* (-2.015)	-.009** (-2.156)
real per capita GDP growth	.707*** (3.271)		.293* (.1.696)		-.089 (-.419)
population growth	-1.652*** (-2.632)		-.480 (-1.076)		
growth of per capita GERD in US PPP$		-.265* (-1.933)		-.033 (-.200)	
growth of researchers (headcount) per million inhabitants		.435** (3.028)		.409* (1.841)	.343** (2.392)
growth of gross tertiary enrolment ratio					.136 (.879)
R^2	.108	.295	.060	.140	.188
F	7.128 (.000)	3.210 (.042)	3.906 (.010)	1.960 (.137)	2.264 (.080)
N	180	27	187	40	44

Note: Dependent variable is the growth of scientific output per million inhabitants. Results refer to unstandardised coefficients of linear regression models. The S&T capacity model could not be estimated for 1993-2000 for lack of enrolment data. T-values in brackets. * p<.10, ** p<.05, *** p<.01.

5. Growth trajectories and the change in specialisation

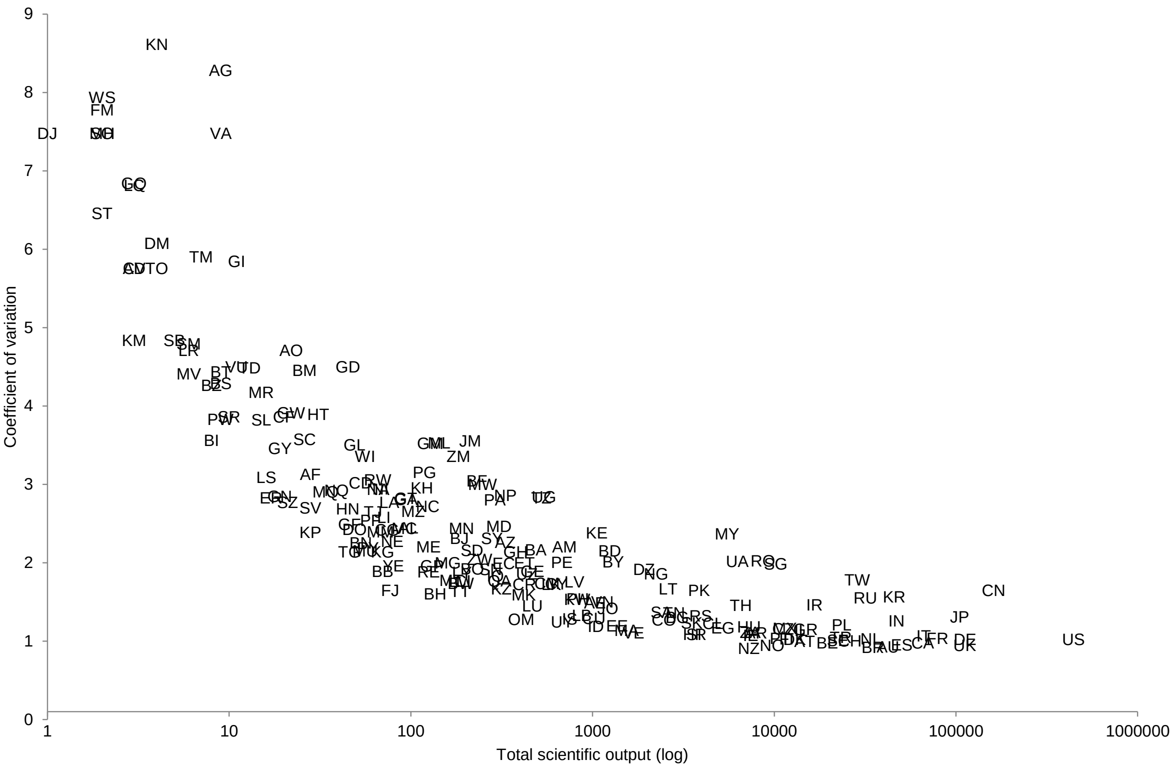
A country is more specialised if its scientific output is concentrated in fewer research areas. One may expect that smaller science systems are more specialised, because they cannot be active in as many fields as large systems can. We therefore expect an inverse relationship between the size of a science system and its degree of specialisation. Also, as a science system grows, its degree of specialisation declines. Our convergence estimates suggest that, at least after 2000, small science systems achieved higher growth rates than large science systems. Therefore we expect convergence in specialisation levels.

[6] The same models were tested for total output and output per unit of GDP. The results confirm the outcomes of Table 1. In 1993-2000, there is neither convergence nor divergence in total output and conditional convergence in output per unit of GDP. In 2000-2008, all models show conditional convergence.

Understanding scientific specialisation requires that we account for three distinct but interdependent variables (Mangani, 2007): the number of research domains in which a country is active as an indication of scientific *variety*, average output per research domain as an indication of the *intensity* of scientific activity, and the distribution of output among research areas as an indicator of scientific *focus*, i.e. the overall degree of specialisation.

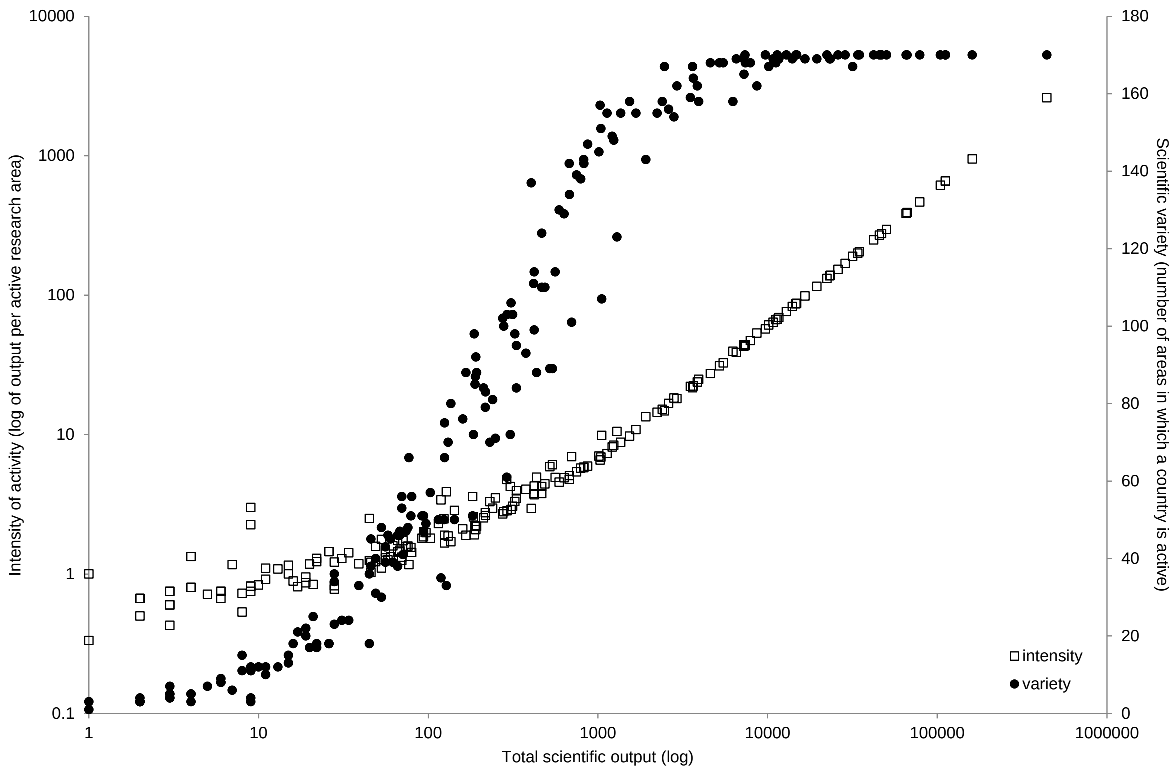
We have used the coefficient of variation to measure how output is dispersed among the 170 research areas.[7] Figure 1 shows that there is an inverse relationship between size and focus. Figure 2 confirms that large science systems have higher variety: they are active in more research areas than small systems. It also shows that large science systems have higher intensity: they produce more output per research area than small systems. The nature of the relation between output and activity is, however, not straightforward. The intensity of scientific activity shows a strong log-linear relationship, whereas the relationship between output and scientific variety has the shape of an S-curve.

Figure 1. Total scientific output versus scientific focus, 2008 (logarithmic scales)
Note: Country codes correspond to ISO 3166-1.



[7] Concentration and specialisation indices are used in a wide variety of disciplines to measure how data are distributed across populations and samples. There are examples from international trade (e.g., De Benedictis & Tamberi, 2004), technology and R&D (e.g., Malerba & Montobbio, 2003; Mansfield, 1981), market analysis (e.g., Ginevicius & Cirba, 2009), and regional economics (e.g., Moreno, Paci, & Usai, 2005), but the list includes biology (Gorelick & Bertram, 2007) and genetics (Martínez & Reyes-Valdés, 2008). The advantage of the coefficient of variation is that it is not scale-dependent. Any set of equal values produces a coefficient of zero.

Figure 2. Total scientific output versus scientific variety (left axis) and intensity of scientific activity (right axis), 2008



We can infer from Figure 2 that different groups of countries exhibit different patterns of growth and specialisation. Small science systems grow by increasing variety, expanding into new areas. Medium-sized science systems grow through a combined increase in intensity and variety. And the growth of large science systems, which are active in (nearly) all research areas, almost entirely results from an increase in the intensity of scientific activity. In other words, the relationship between size and specialisation is not uniform but segmented.

The next question is if these segments are part of one growth trajectory or if different groups of countries follow different growth trajectories. Do relationships between science system size (in terms of output) and the statistical components of the growth process (variety; intensity; focus) persist over time? If they do and there is no lateral movement of the curves, countries follow a common trajectory, the S-curve in Figure 2. If they do not and there is lateral movement of the curve, there are different country clusters each with their own, particular growth trajectory. Chow tests, using the years as breakpoints, show that the relationships are identical.[8] The tests show that the data for 1993, 2000, and 2008 should be treated as one set rather than as three separate sets. The absence of lateral movement of the curves and their identical shape

[8] When the graphs for the relationship between (the log of) total scientific output and its statistical components are superimposed, the curves appear to be identical. The graphs for 1993 and 2000 are replicas of Figures 1 and 2.

suggest that countries move along a common growth trajectory. In conclusion, as a science system grows, it expands its activities into new research areas and intensifies its activities within research areas. Small science systems focus more on expansion, larger systems more on intensification.

Figure 1 shows that there is a considerable number of outliers, representing science systems that have a higher degree of specialisation for their size. These countries – e.g. China, Malaysia, Kenya, Jamaica, South Korea – may have different specialisation strategies than other countries. Common countries follow the growth trajectory of Figure 2 and diversify as they expand into new research areas. The outliers expand and diversify but as they grow their output remains concentrated in fewer areas than in other countries.

6. Convergence between national research portfolios

Up to now we focused on convergence in size and in levels of specialisation, and we indeed found convergence. Here we examine whether we also find increasing similarity in the structure of scientific output. We have compared every country's scientific portfolio with an unweighted average world output structure – using chi-square statistics (Archibugi & Pianta, 1992) – to assess to what extent national patterns of specialisation are different from that of the entire world in 1993, 2000, and 2008.[9] The results show convergence. The majority of countries experienced continuous convergence between 1993 and 2008 (85 countries) or, at the very least, divergence in 1993-2000 followed by convergence in 2000-2008 (61 countries). The trend is towards greater similarity: over time the research portfolios of countries are becoming more similar to the structure of the global portfolio.[10]

This type of convergence may be also an effect of the classification we have used: if a country is active in all research fields distinguished in the classification, there is simply no room left for large science systems to grow by expanding into new research areas. Any further diversification in scientific output occurs within rather than between categories and remains out of sight of the classification used in this paper. More precisely, as countries expand into new research areas, the probability of similarity to world output increases. While smaller countries can expand into new areas and gradually approach the activity set of larger countries, the largest countries cannot as they are already active in all areas.

[9] If we were to use the actual (i.e. weighted) structure of world output as a reference point, we would really be asking to what extent national output structures resemble those of the USA, China, Japan, the UK and a few other major scientific producers. This is why we use an unweighted average.

[10] This type of convergence may be also an effect of the classification we have used: if a country is active in all research fields distinguished in the classification, there is simply no room left for large science systems to grow by expanding into new research areas. Any further diversification in scientific output occurs within rather than between categories and remains out of sight of the classification used in this paper. More precisely, as countries expand into new research areas, the probability of similarity to world output increases, and while smaller countries can expand into new areas and gradually approach the activity set of larger countries, the largest countries cannot as they are already active in all areas.

However, substantive agenda setting is a more likely driver of the increasing similarity in national scientific portfolios: similar nations make (partly) similar choices. In order to understand the dynamics of convergence in scientific portfolios more precisely, we conduct factor analysis on national research portfolios. This may show whether there is convergence towards a ‘unified research agenda’ or whether convergence occurs within discrete clubs.

As we argued in section two, scientific agenda setting is driven by global dynamics as well as local dynamics. If local conditions have effects, the scientific output structures of countries will correlate stronger with those of countries that have the same socio-economic (or regional) characteristics than with the output structures of other countries. Factor analysis will show this by clustering countries into a number of factors, each representing a set of comparable countries. There should also be little or no correlation between the factors. Insofar as globalisation plays a role, we expect countries to cluster into a decreasing number of ever larger factors and the factors themselves to correlate increasingly strongly.

We have clustered countries using an orthogonal rotation (Varimax) based on the distribution of their scientific output across 170 research areas. At the default eigenvalue of one (the Kaiser criterion), the result is a factor structure of 37 factors in 1993, 38 in 2000, and 31 in 2008. The Kaiser criterion is known to overestimate the number of factors (Lance, Butts, & Michels, 2006), which is why we have applied parallel analysis to determine the right number of factors (Hayton, Allen, & Scarpello, 2004; Lance, Butts, & Michels, 2006). The results of parallel analysis suggest constraining the factor analysis to 14 factors in 1993, 12 factors in 2000 and 9 factors in 2008. In 2000, the tail of the factor distribution is poorly interpretable, consisting mainly of loadings below 0.4. This is why we have constrained this particular factor solution to 10 factors. The factors are interpretable and intuitively correct.[11]

We can conclude that the science systems of the world cluster into a declining number of factors, with little correlation among the factors. There does not appear to be convergence to one global scientific agenda. The world divides into discrete *scientific convergence clubs*, and over time countries move between convergence clubs as their portfolio changes. Table 4 shows the portfolios of the nine convergence clubs in 2008. The precise clustering of countries in 1993, 2000, and 2008 can be found in Annex I.

[11] We have also tested an oblique rotation (Direct Oblimin), which assumes that the resulting factors may be correlated. Oblique rotation produces a component correlation matrix that shows no significant correlation among factors. This suggests that there is no global macrostructure and that research agendas are primarily driven by nation-specific forces. A comparison of the rotated component matrix of an orthogonal rotation with the structure matrix of an oblique rotation shows that the factor solutions are essentially the same. The factors represent the same types of clusters, appear in roughly the same order, and contain the same countries. Finally, the tails of each factor consist of countries that have relative low loadings on the factor, indicating that these countries are less similar to the factor than the ones with a higher loading. We have excluded countries that do not load significantly (i.e. a loading lower than 0.3) on a factor from the tables.

Table 4. Unweighted average share of scientific categories in total output per factor in 2008 (%)

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9
1 Natural sciences	**42.5**	**29.6**	**36.4**	**57.2**	**67.4**	**31.3**	**37.6**	**69.0**	**43.4**
1.1 Mathematics	3.5	0.8	2.0	7.1	0.3	2.6	1.5	1.7	0.9
1.2 Computer and information sciences	7.8	0.5	3.7	1.8	0.6	3.4	2.0	2.0	2.2
1.3 Physical sciences	9.9	1.3	6.6	24.4	1.1	3.9	1.4	23.1	6.1
1.4 Chemical sciences	6.7	1.9	4.8	15.2	3.6	4.8	4.4	1.9	8.5
1.5 Earth and related environmental sciences	4.7	6.5	4.6	2.9	16.0	7.0	6.6	26.3	9.3
1.6 Biological sciences	9.9	18.6	14.8	5.7	45.8	9.7	21.7	14.0	16.4
2 Engineering and Technology	**28.8**	**5.7**	**13.6**	**21.4**	**5.2**	**14.5**	**11.3**	**7.5**	**7.6**
2.1 Civil engineering	1.4	0.4	0.6	0.8	0.1	0.7	0.1	1.3	0.2
2.2 Electrical, electronic, and information engineering	12.5	0.7	4.5	5.4	1.3	5.8	2.0	1.8	3.5
2.3 Mechanical engineering	2.8	0.5	1.3	2.8	0.6	1.3	0.9	0.7	0.0
2.4 Chemical engineering	1.1	0.1	0.5	0.7	0.0	0.6	0.3	0.4	0.0
2.5 Materials engineering	3.9	0.4	2.0	7.2	0.1	1.5	0.6	0.6	0.9
2.6 Medical engineering	0.9	0.6	0.8	0.6	0.1	0.3	0.7	0.1	0.2
2.7 Environmental engineering	2.4	0.8	1.1	1.4	1.3	1.7	1.1	1.3	0.0
2.8/9 Environmental and industrial biotechnology	1.0	1.3	0.9	1.1	0.6	0.4	1.8	0.4	1.8
2.10 Nanoscience & Nanotechnology	0.8	0.1	0.5	0.9	0.0	0.2	0.1	0.2	0.0
2.11 Other engineering and technologies	2.0	0.9	1.3	0.7	0.9	1.9	3.6	0.7	0.9
3 Medical and Health Sciences	**24.7**	**57.8**	**46.1**	**15.8**	**22.2**	**48.2**	**25.5**	**17.4**	**39.7**
3.1 Basic medicine	6.3	8.5	13.0	5.2	5.7	7.3	5.2	4.0	11.3
3.2 Clinical medicine	14.2	14.3	28.0	8.8	9.6	30.4	12.4	8.3	10.2
3.3 Health sciences	4.2	35.0	5.1	1.7	7.0	10.4	7.9	5.1	18.3
4 Agricultural Sciences	**3.3**	**6.2**	**3.3**	**0.8**	**4.8**	**2.2**	**24.3**	**4.8**	**5.0**
4.1 Agriculture, forestry, and fisheries	1.7	3.7	1.4	0.5	3.6	1.5	11.0	2.4	2.7
4.2 Animal and dairy science	0.9	1.6	0.8	0.2	0.3	0.4	3.5	1.1	1.2
4.3 Veterinary Sciences	0.7	0.9	1.1	0.1	0.9	0.2	9.9	1.4	1.2
5 Multidisciplinary Sciences	**0.7**	**0.7**	**0.6**	**4.9**	**0.4**	**3.8**	**1.3**	**1.3**	**4.3**
1-5 Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Average output size	13,105	162	37,471	3,454	78	157	472	561	34
Median output size	2,396	79	12,931	435	26	80	77	66	21

Notes: We use a revised classification of science of the OECD's Frascati Manual to classify the subject areas of the Web of Science (OECD, 2002, p. 67, 2007). A small number of subject areas was not included or was divided among a number of classes (notably, biotechnology); their classification required some additional effort. The classification is available upon request. Total output is defined as the sum of output in subject areas, which means that papers belonging to multiple subject areas are double counted.

The convergence clubs have been named according to the socio-economic and political nature of the countries in each factor and the salient features of their scientific portfolio. In the earlier years, many emerging countries clustered together with the former Soviet Union to form a cluster of the former USSR and planned economies. Also, the LDCs were divided among a number of different, smaller clusters. In 1993 we also found a group of (former) French, Belgian, and Portuguese colonies, including Rwanda, Guinea-Bissau, French Guiana, and Haiti. The names do not always exactly match every single country in a club, but they give a general impression of its nature.

Table 5 presents the scientific specialisations of the countries in each factor in 2008. As the table indicates, the developed countries heavily specialize in medical and life sciences, whereas the emerging economies and the former Soviet Republics focus on natural science and technology.

Table 5. Countries and scientific specialisation per convergence club in 2008

Factor	Convergence club name	Countries characteristic of the factor	Main scientific specialisations
1	Emerging economies	Emerging economies of Asia, such as Iran, Malaysia, Taiwan, China, Thailand, Singapore, South Korea, and India; countries of North Africa and the Middle East, such as Egypt, Algeria, Tunisia, United Arab Emirates and Qatar; New Member States in Eastern Europe, such as Latvia, Lithuania, Poland, and including Finland	computer science; physical sciences; electrical engineering and other domains of engineering
2	Less developed countries 1	Less developed countries in Africa (e.g. Tanzania, Burkina Faso, Angola, Mali, Kenya), South and Central America (e.g. Peru, Haiti, Nicaragua, Guatemala), and Asia (e.g. Cambodia, Laos, Afghanistan, Papua New Guinea)	health sciences (about one third of output involves infectious diseases, parasitology, tropical medicine, and public health); biological sciences
3	High-income industrialised nations	High-income industrialised nations in the EU15 (e.g. Netherlands, UK, Italy, Sweden, Denmark, Germany), the USA and Canada, South America (Brazil, Argentina, Uruguay), and Oceania (Australia, New Zealand)	clinical medicine and basic medicine; biological sciences
4	Former USSR	Eleven former Soviet Republics (including Russia, Azerbaijan, Ukraine, Belarus, Kazakhstan, and Georgia) as well as Bulgaria and Liechtenstein	chemical sciences; physical sciences; mathematics; materials engineering and electrical engineering
5	Small island nations and ecological strongholds	Small island nations (e.g. New Caledonia, Bermuda, Seychelles, Bahamas, French Polynesia, Marshall Islands, and Micronesia) and countries with an abundance of species, high biodiversity or a highly characteristic ecosystem (Panama, Costa Rica, Belize, Greenland)	earth and environmental sciences; biological sciences of which 85% involves biodiversity research, zoology, entomology, and other biology
6	Mostly former British colonies	Six of the seven countries in factor 6 are (former) British colonies (Jamaica, Antigua & Barbuda, Brunei, Yemen, Trinidad & Tobago, and Barbados) as well as Bosnia Hercegovina	clinical medicine; electrical engineering
7	Less developed countries 2	A second, smaller group of less developed countries (Guinea, the Philippines, Nigeria, St. Kitts & Nevis, Vanuatu, Fiji, and Guadeloupe)	agricultural sciences; biological sciences (one third consists of plant science); food science and technology (in other engineering and technology)
8	Less developed countries 3	Namibia, Kyrgyzstan, Botswana, Gibraltar, Vatican, Bhutan, Antarctica, Albania, Chile	natural sciences (physical, earth and environmental, biological), agricultural sciences
9	Southern Africa	Three countries in Southern Africa (Rwanda, Swaziland, Lesotho)	biological sciences; chemical sciences; earth and environmental sciences; medical and health sciences (almost 15% of output in infectious diseases, parasitology, tropical medicine, and public health), agricultural sciences

Since 1993, the clustering of science systems has changed considerably (Table 6). The group of emerging economies has grown exponentially, from a mere seven countries in 1993 to 16 in 2000 and 58 in 2008. Many of these countries were first located among the former USSR and planned economies. Among the Less Developed Countries (LDCs) we see a concentration of countries in fewer clusters, indicating that their portfolios are becoming increasingly similar. The main cluster of LDCs grew from 39 to 53 countries. While the remaining clusters of LDCs shrank from 37 to 14 countries, the group of (former) British colonies also declined. At the tail end of the factor structure small clusters of countries appeared and disappeared.

Table 6. Factor structures in 1993, 2000 and 2008 (number of countries in each factor between brackets)

Factor	1993	2000	2008
Emerging economies	8 (7)	6 (16)	1 (58)
Less developed countries 1	1 (39)	2 (44)	2 (53)
High-income industrialised nations	3 (27)	3 (29)	3 (25)
Former Soviet Republics and planned economies	2 (35)	1 (39)	•
Former Soviet Republics	•	•	4 (11)
Ecological strongholds and small island nations	7, 11 (15)	7, 10 (19)	5 (15)
Mostly former British colonies	5 (16)	4 (14)	6 (7)
Former French, Belgian, Portuguese colonies	6 (6)	•	•
Less developed countries 2, 3, 4, 5	4, 9, 10, 13 (37)	5, 8, 9 (27)	7, 8 (14)
Southern Africa	•	•	9 (3)
Oil-producing nations	12 (5)	•	•
Other countries	14 (5)	•	•
Number of factors	*14*	*10*	*9*
Total number of countries	*192*	*188*	*195*

See the annex for the countries in each factor.

Notes: The numbers refer to the location of each cluster of countries in the factor analysis. For example, in 2008 the emerging economies are the highest cluster in the factor structure, which means that their portfolio contributes most to explaining the portfolio of world scientific output.

Finally, we have run factor analysis across the factor solutions for 1993, 2000, and 2008 to find out which convergence clubs cluster together, using the unweighted average output structure of countries within each cluster as input (Table 7). In 1993 and 2000 the result is a three-factor solution in which the third factor consists of small and heterogeneous clusters of countries that also load on the LDCs. In 2008, only two factors remain.

A clear dichotomy emerges. The world is divided between a group of highly developed – 'established' – science systems (the former Soviet Republics, the emerging economies, and the high-income industrialised nations) and the developing world and former colonies. There is little significant correlation across the divide. There are about nine discrete convergence clubs and perhaps two meta-clubs: the 'North' and the 'South'.

Table 7. Results of factor analysis across factors

1993	**Factor 1**	**Factor 2**	**Factor 3**
Former USSR and planned economies	.852		
High-income industrialised nations	.827		
Emerging economies	.774		
Other countries	.595		
Oil-producing nations	.545		
Mostly former British colonies	.519	.469	
Former French, Belgian, Portuguese colonies		.804	
LDCs 1		.792	.426
LDCs 3		.692	
LDCs 2		.536	.528
Ecological strongholds, small island nations 2			.690
Ecological strongholds, small island nations 1			.690
LDCs 4	.490		.510
LDCs 5			.465
2000	**Factor 1**	**Factor 2**	
LDCs 1	.846		
LDCs 2	.818		
LDCs 3	.762		
Mostly former British colonies	.586	.484	
Ecological strongholds, small island nations 1	.568		
LDCs 4	.517		
Ecological strongholds, small island nations 2	.396		
Former USSR and planned economies		.941	
Emerging economies		.894	
High-income industrialised nations		.836	
2008	**Factor 1**	**Factor 2**	
Emerging economies	.910		
High-income industrialised nations	.845		
Former USSR	.808		
LDCs 3	.644	.398	
LDCs 1		.883	
LDCs 2		.777	
Southern Africa		.716	
Small island nations and ecological strongholds		.640	
Mostly former British colonies	.454	.487	

Note: Factor analysis across the unweighted average output structure for each group of countries.

7. Analysis

Our results show that there is convergence in levels of scientific output: small science systems are growing faster than large systems and international differences in output per capita are decreasing. We find that the structure of global scientific output is not converging towards a unified research agenda. In 2008 worldwide science divides into nine convergence clubs and two meta-clubs.

There are considerable differences in scientific and economic performance among the convergence clubs. Most remarkable is the rapid rise of the emerging economies.[12] Using the factor distribution of 2008, Tables 8 and 9 show how the emerging economies are rapidly converging on the high-income industrialised countries. In 2008 their indicators of S&T capacity were still lower, but growth has been substantial faster. Also, their scientific output is rapidly diversifying as they expand into new scientific areas.

The performance of the lower six country clusters in Table 8 – the ‘South’ – helps explain the convergence of output levels. These relatively small science systems experienced high output growth, driven particularly by an expansion into new areas. Total output remains small, which is reflected in high coefficients of variation in 2008, an indication of strong focus in the portfolio of these countries. In addition, the former Soviet Republics are being left behind: output growth is relatively low, the researcher population is in decline and R&D investments are decreasing.

Table 8. Scientific output growth experience of convergence clubs, 1993-2008 (%) and degree of specialisation in 2008

	annual output growth	annual growth in per capita output	annual change in variety	annual change in intensity of activity	annual change in degree of specialisation	coefficient of variation in 2008
Emerging economies	8.1	8.6	1.8	7.3	-1.3	1.60
High-income industrialised nations	3.7	4.2	0.5	3.7	-1.2	1.85
Former USSR	1.7	6.5	1.5	1.1	-0.9	2.34
LDCs 3	8.0	6.9	2.3	4.4	-0.5	4.59
LDCs 1	6.9	4.3	3.1	2.5	-1.4	3.16
LDCs 2	6.3	6.5	2.3	2.6	-0.8	3.29
Southern Africa	3.8	1.5	3.4	0.2	-1.6	2.98
Small island nations and ecological strongholds	6.6	6.8	3.7	2.1	-1.5	4.08
Mostly former British colonies	7.9	6.4	3.8	3.5	0.6	3.11

Note: Compound annual growth rates.

[12] The estimates of β- and σ-convergence are not affected when we exclude the emerging economies.

Table 9. Indicators of S&T capacity of convergence clubs, 1993-2008

	annual growth in researcher population [a)]	researchers per million inhabitants 2007	annual growth in GERD ratio to GDP [a)]	GERD as a percentage of GDP 2007	population growth 1993-2008	annual growth per capita GDP 1993-2008	per capita GDP in 2008
Emerging economies	4.0	2,655	0.7	1.04	1.2	2.9	10,244
High-income industrialised nations	2.2	4,460	2.4	1.88	0.9	2.3	20,272
Former USSR	-4.1	1,417	-2.7	0.48	-0.2	3.4	8,098
LDCs 3	2.4	660	-7.2	0.23	1.2	3.7	2,001
LDCs 1	4.4	111	1.3	0.17	2.5	2.4	1,004
LDCs 2	n/a	164	n/a	n/a	2.3	2.0	1,950
Southern Africa	n/a	n/a	n/a	n/a	2.8	1.6	835
Small island nations and ecological strongholds	-4.8	242	n/a	n/a	1.9	2.6	18,947
Mostly former British colonies	7.4	652	-5.0	0.06	2.4	2.6	7,296

a) 1996-2007

Our findings agree with the observation of The Royal Society that we are living "in increasingly multipolar scientific world, in which the distribution of scientific activity is concentrated in a number of widely dispersed hubs." (Royal Society 2011) The number of scientific hubs is increasing. In terms of performance, new hubs are catching up with the scientific leaders in the OECD. Countries such as China, India, Brazil, Iran, and Saudi Arabia are rapidly moving up global scientific rankings.

Yet, each hub has a distinctive pattern of specialisation. Overall, worldwide science appears to be converging towards five typical specialisation patterns: (1) the OECD with a focus on medicine and biology, (2) emerging economies with a focus on electrical engineering and natural sciences, (3) Less Developed Countries with a focus on health sciences, (4) small island nations and ecological strongholds with a focus on earth sciences, environmental science, and biology, and (5) the former USSR with a focus on physics, chemistry, and engineering. The OECD, the small island nations and ecological strongholds, and the former USSR are stable clusters. The process of convergence is driven by the emerging economies and the LDCs.

The BRICS – Brazil, Russia, India, China, and South Africa – are frequently presented as the economies that will dominate the world in the future, the new hubs of a multipolar world. Our results suggest that, in science, they should not be considered as one group.

The scientific portfolio of Brazil resembles that of the USA and other high-income industrialised nations, albeit with a stronger focus on agricultural research. Brazilian researchers prefer publishing in national and regional journals, in their own language, and increasingly in collaboration with researchers from neighbouring Latin American countries (Glanzel, Leta, & Thijs, 2006).

Russia clusters among the former Soviet Republics and has an obsolete scientific portfolio. The falling apart of the Soviet Union had dramatic effects on Russian science and technology (Yegorov 2009; UNESCO 2010). Since 1990 R&D intensity has dropped severely. Talented researchers are emigrating and the researcher population is ageing. There is a lack of modern research equipment and not enough money to replace obsolete equipment. Institutional structures are obsolete and government policy appears to be ineffective. What goes for Russia, is equally true for the other former Soviet Republics. The experience of Russia is in stark contrast to that of the East European countries that joined the EU in 2004. In 2008, these New Member States were among the rapidly growing emerging economies, possible as a result of access to European Framework Programme funding.

China and India are leaders among the emerging economies, growing very rapidly and focusing their research portfolio heavily towards more dynamic areas of technology (e.g. nanotechnology) and the natural sciences (e.g. advanced materials). China is currently the most dynamic science and innovation system in the world. The prediction is that by 2013 China will have overtaken the USA as the largest producer of scientific publications in the world (Royal Society 2011). The quality of scientific publications – in terms of citations per publication – is still lagging behind, though it appears a matter of time before the quality of Chinese science catches up (Leydesdorff and Zhou 2005).

South Africa is the most advanced economy of Africa. And yet, in 2008 its scientific portfolio resembled that of most LDCs. One possible explanation is the rise of HIV/AIDS (see also Pouris, 2010). South Africa has the most people in the world suffering from HIV/AIDS. A search for the number of publications with the word HIV in Thomson Reuters Web of Science reveals that HIV/AIDS-related research accounts for 0.9% of South African scientific output in 1993, 3.8% in 2000, and 9.0% in 2008. As a result, the portfolio of South Africa is a mix between two scientific worlds.

8. Conclusions and discussion

There is convergence in worldwide science. The per capita scientific output of smaller countries grows faster than that of larger countries. In addition, all countries show a decrease in the overall degree of specialisation. The national science portfolios of most of the world's countries are becoming increasingly similar. The evidence on the two interpretations of convergence concurs.

Yet, the world remains divided. Small countries are slowly catching up, but large science systems continue to dominate global science.[13] Growth is a general phenomenon in science, but most countries retain their relative position as a large, medium-sized or small science system. Only a small number of countries (such as Iran) has managed to simultaneously achieve rapid expansion into new research areas and an intensification of activities in each area. These countries are swiftly moving up the rankings.

The scientific *output* of nations may follow a common growth trajectory, but there is no common development trajectory for science *portfolios*. The science systems of the world are not converging towards a global scientific agenda or a single system. Rather, there are convergence clubs, each with their own discrete specialisation pattern and structural characteristics. We found a minimum of nine convergence clubs and a dichotomy between developed and developing nations – 'North' and 'South' – a dichotomy that appears to be widening. Underneath the dynamics of output growth and portfolio change, worldwide science appears to have a stable structure. Most countries remain within their convergence club or shift to comparable clubs. Since 1993, few countries have managed to move from 'North' to 'South'.

A major question in science policy concerns the power of coordination and the possibility of guiding the (national) scientific community towards a more desirable research agenda. Is it possible for convergence clubs to escape the restrictions of their specialisation pattern?
It is undeniable that science has become a global enterprise. In many fields, the dynamics of agenda setting are driven by a worldwide discourse. An increasing proportion of scientific publications is written in inter-institutional and international collaboration (Wagner & Leydesdorff, 2005). The substance of science knows no boundaries and in this respect we can understand globalisation as a process of local self-organisation by individual scientists, research groups and knowledge institutes.

While scientists may view themselves as part of a global community, national boundaries still matter. Science policy is primarily driven by national interests. Individual actors in the science system may work in an international setting, but the lion's share of funding originates in national government budgets and investment programmes. Coordination, agenda setting, and

[13] A small proportion of countries accounts for the vast majority of publications. In 2008, the ten largest scientific producers in the world, including the USA and China, account for about 67% of world output; the 40 largest for about 95%; the remaining 160-plus countries account for at most 5%.

policy making also predominantly take place within national science systems. The institutional framework of science remains domestic (Carlsson, 2006).

The ability of countries to improve their local conditions and escape the strictures imposed by their portfolio depends on the interplay of forces along two dimensions. First, there is the tension between short-term dynamics and long-term stability. This sets the creativity of and competition among self-organising scientists against the initial conditions, structural features, and vested interests of science systems. How much leeway do individual researchers have to set new directions and mobilise the required resources? Then, there is the tension between the complexity of science and the predominance of national policies and institutions. What is the power of policy makers and decision makers to guide the system and change the behaviour of entire communities of actors? These questions are highly relevant where it concerns international competition in science, technology and innovation. Understanding the design and functioning of a science system in all its complexity is crucial to survive in a world of different speeds with intense competition and persistent gaps between rich and poor. For scientists and policy makers alike, selecting the right science portfolio and knowing the competition are key issues.

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Annex I: Factor structures, 1993-2008

Factor structure, 1993

<table>
<tr><th>1. LDCs 1</th><th>2. Former USSR and planned economies</th><th>3. High-income industrialised nations</th><th>5. Mostly former British colonies</th><th>9. LDCs 3</th></tr>
<tr>
<td rowspan="11">Sudan
Equatorial Guinea
Congo
Senegambia
Malawi
Tanzania
Sierra Leone
Belize
Togo
Liberia
Burkina Faso
Cameroon
Zambia
Madagascar
Gabon
Central African Republic
Ethiopia
Honduras
Kenya
Zimbabwe
Vanuatu
Djibouti
Burundi
Comoros
Nigeria
Nepal
Uganda
Myanmar
Mozambique
Lesotho
Côte d'Ivoire
Peru
Thailand
Benin
Andorra
Nicaragua
Bolivia
Ecuador
Paraguay</td>
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Ukraine
Poland
Kazakhstan
Moldova
China
Bulgaria
India
Byelarus
Azerbaijan
South Korea
Slovenia
Algeria
Armenia
Morocco
Czechoslovakia
Georgia
Croatia
Lithuania
Portugal
Uzbekistan
Romania
Hungary
Egypt
Tajikistan
Yugoslavia
Vietnam
Latvia
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Denmark
Netherlands
USA
Canada
Belgium
Finland
Italy
Norway
Switzerland
Israel
Austria
France
United Kingdom
Germany
Argentina
Australia
Uruguay
Spain
Japan
Mexico
Brazil
Greece
Iceland
Guatemala
Malaysia
Luxembourg</td>
<td>Gibraltar
Saudi Arabia
Greenland
Jamaica
South Africa
Ireland
Chile
New Zealand
Papua New Guinea
Barbados
Cambodia
Kyrgyzstan
Trinidad & Tobago
Tunisia
Oman
Brunei</td>
<td>Bophuthatswana
Guadeloupe
West Indies
Angola
Cuba
Iraq
Dominican Republic</td>
</tr>
<tr><th>6. Former French, Belgian, Portuguese colonies</th><th>10. LDCs 4</th></tr>
<tr><td>Rwanda
Guinea-Bissau
Zaire
Haiti
French Guiana
Martinique</td><td>Guyana
Somalia
Venda
New Caledonia
Pakistan
Mauritius</td></tr>
<tr><th>4. LDCs 2</th><th>7. Ecological strongholds, small island nations 1</th><th>11. Ecological strongholds, small island nations 2</th></tr>
<tr>
<td rowspan="7">Syria
Niger
Philippines
Surinam
Colombia
Tonga
Mali
Cape Verde
Ghana
Sri Lanka
Costa Rica
Samoa
Fiji
Chad
Western Samoa
Ciskei
Indonesia
Botswana
Bhutan
Bangladesh</td>
<td>Cook Islands
Bermuda
St. Lucia
Monaco
Palau
Mauritania
French Polynesia
Bahamas
Transkei
Seychelles</td>
<td>Namibia
El Salvador
Panama
Turkmenistan
Netherlands Antilles</td>
</tr>
<tr><th>8. Emerging economies</th><th>12. Oil-producing nations</th></tr>
<tr><td rowspan="5">Singapore
Taiwan
Bahrain
Jordan
Bosnia & Herzegovina
Kuwait
Micronesia</td><td>Yemen
Venezuela
Libya
Albania
United Arab Emirates</td></tr>
<tr><th>13. LDCs 5</th></tr>
<tr><td>Grenada
Laos
Solomon Islands
Dominica</td></tr>
<tr><th>14. Other countries</th></tr>
<tr><td>Tuvalu
Turkey
Guinea
Lebanon
Cyprus</td></tr>
</table>

Factor structure, 2000

<table>
<tr><th>1. Former USSR and planned economies</th><th>2. LDCs 1</th><th>3. High-income industrialised nations</th><th>5. LDCs 2</th><th>7. Ecological strongholds, small island nations 1</th></tr>
<tr><td rowspan="7">Russia
Ukraine
Byelarus
Romania
China
Morocco
Poland
Bulgaria
Algeria
Moldova
Czech Republic
India
Armenia
Lithuania
Azerbaijan
Slovakia
Egypt
Georgia
South Korea
Uzbekistan
Portugal
Latvia
Mexico
Tunisia
Iran
Slovenia
Japan
Yugoslavia
Hungary
Kazakhstan
Pakistan
Estonia
Cuba
Vietnam
Colombia
North Korea
Kyrgyzstan
Liechtenstein
Mongolia</td><td rowspan="7">Gambia
Gabon
Malawi
Zambia
Senegal
Tanzania
Comoros
Uganda
Burkina faso
Central African Republic
Ghana
Cameroon
Sudan
Equatorial Guinea
Sao Tome and Principe
Côte d'Ivoire
Congo
Somalia
Mozambique
Nepal
Papua New Guinea
Guinea-Bissau
Angola
French Guiana
Zaire
Kenya
Peru
Zimbabwe
Togo
Ethiopia
Nicaragua
Myanmar
Madagascar
Laos
Bangladesh
Guadeloupe
Seychelles
Burundi
Dominican Republic
Sierra Leone
Suriname
Cambodia
Ecuador
Bolivia</td><td rowspan="3">Netherlands
Canada
Sweden
USA
Denmark
United Kingdom
Finland
Austria
Belgium
Italy
Switzerland
Israel
Australia
Germany
France
Norway
Uruguay
Spain
Ireland
Argentina
Greece
Brazil
Lebanon
Chile
Turkey
Luxembourg
New Zealand
Guatemala
Venezuela</td><td rowspan="3">Syria
Philippines
Maldives
Mali
Nigeria
Sri Lanka
Benin
Mauritania
Niger
Eritrea
Costa Rica
Reunion
Albania
Swaziland</td><td>French Polynesia
Andorra
Bahamas
Solomon Islands
Netherlands Antilles
Cook Islands
Bermuda
New Caledonia
Iceland
Monaco
Vanuatu
Barbados
Guinea
Micronesia
Martinique</td></tr>
<tr><th>8. LDCs 3</th></tr>
<tr><td>Namibia
Brunei
Lesotho
Greenland
Bhutan
Panama
Indonesia
Botswana
Guyana
Chad</td></tr>
<tr><th>4. Mostly former British colonies</th><th>6. Emerging economies</th><th>9. LDCs 4</th></tr>
<tr><td rowspan="3">Cape Verde
Jamaica
Saudi Arabia
Trinidad & Tobago
Dominica
Oman
Yemen
Haiti
Fiji
San Marino
South Africa
West Indies
El Salvador
Bosnia & Herzegovina</td><td rowspan="3">Malaysia
Libya
Taiwan
Singapore
Iraq
Thailand
Macedonia
Jordan
United Arab Emirates
Malta
Mauritius
Kuwait
Croatia
Bahrain
Cyprus
Qatar</td><td>Rwanda
Grenada
Paraguay</td></tr>
<tr><th>10. Ecological strongholds, small island nations 2</th></tr>
<tr><td>St. Lucia
Antigua & Barbuda
St. Vincent & The Grenadines
Honduras</td></tr>
</table>

Factor structure, 2008

<table>
<tr><th>1. Emerging economies</th><th>2. LDCs 1</th><th>3. High-income industrialised nations</th><th>5. Small island nations and ecological strongholds</th></tr>
<tr><td rowspan="3">Iran
Taiwan
Malaysia
United Arab Emirates
China
Jordan
Cyprus
Tunisia
Singapore
Bangladesh
Thailand
South Korea
Algeria
Romania
Latvia
India
Oman
Libya
Greece
Finland
Qatar
Montenegro
Portugal
Iraq
Egypt
Poland
Malta
Czech Republic
Estonia
Slovakia
Lithuania
Pakistan
Canada
Mexico
France
Ireland
Lebanon
Japan
Spain
Slovenia
Luxembourg
Indonesia
Kuwait
Myanmar
Saudi Arabia
North Korea
Vietnam
Croatia
Syria
Colombia
Serbia
Sri Lanka
Morocco
Macedonia
Bahrain
San Marino
Mongolia
Mauritius
Venezuela</td><td rowspan="3">Tanzania
Burkina Faso
Peru
Angola
Malawi
Kenya
Cambodia
Mali
Haiti
Mozambique
Uganda
Ghana
Chad
Senegal
Gambia
Equatorial Guinea
Laos
Sudan
Afghanistan
Nicaragua
Zambia
Guatemala
Ethiopia
Guinea Bissau
Benin
French Guiana
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Nepal
Congo
Burundi
Zimbabwe
Honduras
Suriname
Papua New Guinea
Bolivia
Gabon
Niger
Central African Republic
Côte d'Ivoire
Sierra Leone
Sao Tome Principe
Cameroon
Zaire
Martinique
Madagascar
Togo
Dominican Republic
Comoros
Solomon Islands
Dominica
Tonga
Ecuador
Eritrea</td><td>Netherlands
Denmark
Sweden
United Kingdom
USA
Italy
Austria
Switzerland
Germany
Israel
Belgium
Norway
Australia
Hungary
St. Lucia
Netherlands Antilles
Argentina
Uruguay
Turkey
Brazil
Western Samoa
New Zealand
Cuba
Iceland
Grenada
Paraguay
West Indies</td><td>New Caledonia
Bermuda
Seychelles
Greenland
Bahamas
French Polynesia
Palau
Micronesia
Panama
Belize
Marshall Islands
Monaco
Reunion
Costa Rica
Djibouti
Maldives</td></tr>
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Azerbaijan
Ukraine
Tajikistan
Armenia
Byelarus
Kazakhstan
Uzbekistan
Moldova
Bulgaria
Georgia
Turkmenistan
Liechtenstein</td><td>Jamaica
Antigua Barbuda
Brunei
Yemen
Bosnia Herzegovina
Trinidad & Tobago
Barbados
7. LDCs 2
Guinea
Philippines
St. Kitts Nevis
Nigeria
Vanuatu
Fiji
Guadeloupe
8. LDCs 3
Namibia
Kyrgyzstan
Botswana
Gibraltar
Vatican
Bhutan
Antarctica
Albania
Chile
9. Southern Africa
Rwanda
Swaziland
Lesotho</td></tr>
</table>