Cutting-Edge Research for the Global Knowledge Society[1]

The future of the German science system in the context of international competition

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1. Scientific Excellence is decided on a Global Scale

1.1 Increased international competition through globalisation

"Science does not recognise national borders; its limit is simply the limit of human knowledge." Needless to say, Max Planck, who made this statement in 1923, was not the first to identify the international nature of science. Knowledge is universal in nature, therefore research is always international. Many scientists work simultaneously on the same phenomena in different places – one need only think of the theory of natural selection, which was established by Darwin and Wallace in the 19th century, working independently of each other.

Human curiosity and the competition for knowledge and the best ideas are the main driving forces of science. Competition, but also cooperation, are the main shapers of scientific progress: researchers exchange ideas, publish their own findings and assess those of others, build on the latter's ideas, and develop them further.

Today, the dynamics of technical research, the resulting revolution in information, and communications technology and increasing mobility have facilitated the emergence of a completely new dimension in cooperation. The Internet was originally developed to enable better communication between scientists from all over the world who were involved in the international nuclear research centre CERN. In the meantime, *it* has become the crucial factor behind the acceleration of globalisation. This is changing our lives radically: American auditors and accountants have tax declarations carried out anonymously in India and radiologists in US hospitals delegate the evaluation of CT scans to doctors in India.

India is now one of the world's biggest IT service providers and – like China, which is often referred to as the 'workshop of the world' – it is known as the 'back office to the world'. The global division of labour enables national economies to achieve huge gains in efficiency and prosperity. At the same time, it is generating enormous challenges through the competition for innovations and investment – not only in Germany. If the workshops in Asia can already compete with those in Europe and the USA, is it not also possible that the 'laboratory of the world' will be located in India, China, Singapore or Korea in the not-too-distant future?

The development of global value-added systems always goes hand in hand with a research landscape that is increasingly distributed across the globe: large multinational concerns decentralised their research and development activities to locations all over the world a long time ago. They not only locate their R&D activities in big cities or metropolitan regions with a strong tradition in research, but also consciously select locations in newly industrialised countries where they benefit from gains in cost-effectiveness through both the local scientific and technical expertise and the proximity to new sales markets. However, in addition to the aspect of costs and the potential offered by nearby markets, the quality of the local science system, existing R&D activities and an existing industrial culture continue to constitute central decision-making motives when it comes to the selection of locations for research and development.

1.2 The innovation systems in the BRICK states are catching up

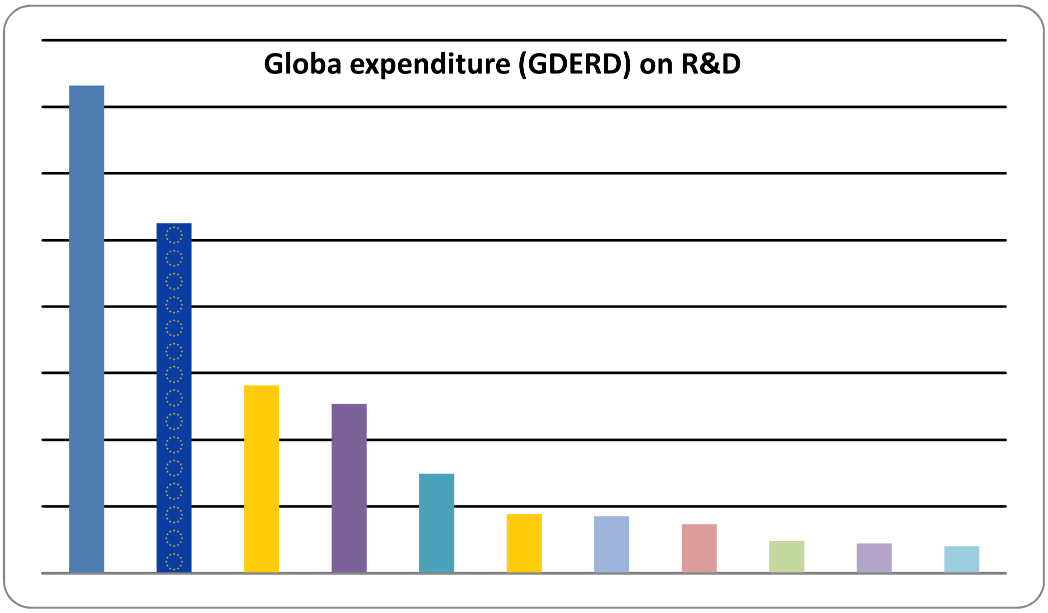

Figure 1: Comparison of research expenditure at global level by G7, EU-27 and selected BRICK[2] countries in 2009 in USD (adjusted for purchasing power at 2005 constant prices). Source: OECD.

Up to now, the majority of knowledge-intensive direct foreign investments were exchanged between the leading research countries of the USA, Japan and Europe. Due to its high-performing innovation system, Germany is a particularly important location for foreign R&D investments, and is even the most important R&D foreign location for companies from the USA. Accordingly, the R&D activities of foreign companies in Germany have tripled over the last 15 years. In addition, multinational concerns employ almost one-quarter of R&D employees in Germany and account for almost one-third of all private-sector R&D expenditure.[3]

However, in recent years it has been possible to observe the emergence of a shift in the focus of the investments made by foreign concerns to the "BRICK States" (Brazil, Russia, India, China, Korea) and other emerging newly-industrialised countries in Asia. Indeed, of the top 20 metropolitan regions that succeeded in attracting the most knowledge-based direct foreign investment between 2010 and 2012, only six were located in Europe; in contrast, five were in India and three in China. Singapore also features among the top five. However, these investments have been concentrated up to now on downstream development tasks,

[2] Unfortunately, the OECD does not have reliable data for India and Brazil. CF. OECD. "Expenditure on R&D". In *OECD Factbook*. Organisation for Economic Co-operation and Development, 2013. http://www.oecd-ilibrary.org/content/chapter/factbook-2013-60-en.

[3] Expertenkommission Forschung und Innovation (EFI). "Gutachten zu Forschung, Innovation und technologischer Leistungsfähigkeit Deutschlands 2013", 2013. http://hdl.handle.net/10419/71411. P. 73

such as concept design and technical application testing, and very little of this funding is expended on original research and high-tech development in these countries.[4]

To attract more foreign investment for cutting-edge technologies and to catch up with the G7 states in this area, China and other countries are making huge investments in science and increasing their public expenditure on cutting-edge research. The BRICK states are not the only countries that have realised that in order to gain access to the traditional high-tech countries in the context of the global competition, they must promote science and innovation through a well-financed public research landscape. Hence, from 1999, annual R&D expenditure in China grew by almost 20 percent. After ten years of constant investment, it overtook Japan in terms of absolute research expenditure in 2009 and has since assumed second place worldwide behind the USA in this sector. With an average annual growth rate of around 10 percent, the resources available for research in Korea also increased significantly over the same period.

These countries' expenditure is also reflected in their increasing performance in the area of research: measured by publications output, their scientific productivity has been increasing continuously in recent years.[5] Steady growth can be observed not only in the quantity, but also the quality of the contributions: for example, 30 percent of all publications listed in the renowned *Nature Publishing Index* for the Asian-Pacific region originate from China.[6] All of the data point to the fact that following China's rise in the context of the global economy, its significance as a research location is now also set to grow. Will China therefore soon replace the USA and become the new scientific superpower? There is no doubt that globalisation has also boosted the importance of the international competition in the world of research – today, more than ever before, scientific competition is decided on a global scale.

1.3 Competition between the regions in the multipolar science system

Despite these huge financial investments in research and development and the resulting growth dynamics, the Asian region will not develop into the world's only cutting-edge research laboratory. With respect to the influence of their publications (measured by citations) and the application of scientific insights (measured by the number of patent registrations), the traditional scientific superpowers like the United Kingdom and the USA will be able to build on their current international leadership position in the area of innovation in the future.[7] Hence, *one* major scientific nation will not replace the other.[8]

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[4] Primi, Annalisa, "The Evolving Geography of Innovation: A Territorial Perspective", in: *The Global Innovation Index 2013: The Local Dynamics of Innovation*, edited by Soumitra Dutta, Bruno Lanvin, Insead, World Intellectual Property Organization, und Johnson Graduate School of Management (Cornell University), 69–78, 2013. http://globalinnovationindex.org/content.aspx?page=gii-full-report-2013. P. 73

[5] Adams, Jonathan, David Pendlebury and Bob Stembridge, *Building Bricks: Exploring the Global Research and Innovation Impact of Brazil, Russia, India, China and South Korea*. Thomson Reuters, 2013.

[6] "Nature Publishing Index 2012 Global | Nature Publishing Group", 2012. http://www.natureasia.com/en/publishing-index/global/supplement2012. P. 24.

[7] Royal Society (Great Britain), *Knowledge, Networks and Nations Global Scientific Collaboration in the 21st Century*. London: The Royal Society, 2011. http://royalsociety.org/uploadedFiles/Royal_Society_Content/Influencing_Policy/Reports/2011-03-28-Knowledge-networks-nations.pdf. P. 5.

Instead, due to the dynamics of globalisation, the map of global cutting-edge research will present numerous competitors in future. A closer look at the different national research systems reveals that the emerging newly industrialised countries are not the only countries, in which the increasing trends for the regional concentration of knowledge and information areas can already be observed today. Regions are developing into the crucial drivers of development in innovative, knowledge-intensive economic areas. The globalisation of economic activity further increased the importance and profile of the region as an 'innovation area'. Regional and local clusters of innovation, as the crucial drivers of the new, are assuming increasing importance for the national and global performance of the knowledge economies. The productive exchange between innovative companies and local research institutes and universities plays a decisive role in this process. In turn, the regionally-based strengths and structures form the basis for the attractiveness of a location that must assert itself in the international context.[9] Similarly, the global competition standard leads to growing international orientation: the high-performing regions are more strongly integrated into global innovation networks – this applies to companies and scientific organisations alike.[10]

In view of these developments, the highly-specialised and high-tech economies of the G7 countries simply cannot afford to ease up: to guarantee and further develop their prosperity, they must remain technologically innovative. China is on the same road and is making every effort to evolve from a 'workshop' to a high-tech-based knowledge economy with the help of original research and development.

Therefore, it may be assumed that we will have a multipolar knowledge system in future, in which a single state no longer dominates, as the USA does today. Instead, several innovative regions will compete as scientific centres for the best innovation locations, the best scientists and the best science.[11] Accordingly, in addition to China, India, South Korea and other former developing and newly-industrialised countries like Brazil are evolving into the new partners and competitors of the established 'research nations' like the USA, Japan and Great Britain, and, naturally also, of the German innovation system.[12] Thus the performance of our science system will have to allow itself be measured even more on a global scale in the future. The internationalisation of the German science system is, therefore, the crucial tool for increasing its performance. This is the only way that it can claim a place at the top of the global scientific league. Together with the USA and Europe, countries like India, China, Brazil and Korea will soon also feature at the top of this league.

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8 Rogers Hollingsworth, J., Karl H. Müller and Ellen Jane Hollingsworth. "China: The End of the Science Superpowers". *Nature* 454, No. 7203 (July 24, 2008): 412–13. doi:10.1038/454412a.

9 Cooke, Philip and Olga Memedovic, *Strategies for regional innovation systems: learning transfer and applications*. United Nations Industrial Development Organization Vienna, 2003. http://www.paca-online.org/cop/docs/P_Cooke_Strategies_for_regional_innovation_systems.pdf P. 15.

10 See also section 2.2 "The local dimension of knowledge dissemination in regional clusters"

11 Rogers Hollingsworth, J., Karl H. Müller and Ellen Jane Hollingsworth. "China: The End of the Science Superpowers". *Nature* 454, No. 7203 (24 July 2008): 412–413. doi:10.1038/454412a.

12 Bundesministerium für Bildung und Forschung, *Deutschlands Rolle in der globalen Wissensgesellschaft stärken. Strategie der Bundesregierung zur Internationalisierung von Wissenschaft und Forschung. (English version: Strengthening Germany's role in the global knowledge society. Strategy of the Federal Government for the Internationalization of Science and Research)*. Berlin, Bonn: BMBF, Referat Grundsatzfragen, Multilaterale Zusammenarbeit, Protokoll, Sprachendienst, 2008.

2. Basic Research as the Basis for Economic Innovation

2.1 Technology leadership is dependent on basic research

The positive scientific development in Asia, and in Brazil and India, would not be conceivable without the corresponding economic growth and targeted investment in the development of expertise. Up to now, these countries' economic growth has been largely based on low wage and raw material costs. As part of their evolution towards more innovation-intensive economic growth, their development is now increasingly dependent on science as the basis of the innovation process. If China wants to produce high-tech goods *'designed in China'* in future, an exclusive focus on application-oriented research will not suffice. Technology leadership is dependent on basic cutting-edge research. The more progress an economy makes in its development, the more dependent it is on basic technical innovations. A study carried out by Hans Gersbach at the Swiss Federal Institute of Technology Zurich (ETHZ) shows that in leading industrialised countries, basic research is the crucial driver of innovation-based economic growth.[13] This is mainly due to the fact that basic research does not focus on improving existing phenomena, but generates fundamentally new knowledge.

It is not even necessary to refer to the much-cited example of *Silicon Valley* to illustrate the key role of basic research as a driver of innovation. A look at German scientific and economic history suffices to demonstrate how closely research is linked with the development of new fields of technology: in the second half of the 19th century, Germany experienced a 'founder's boom' when the manufacturers of synthetic paints mushroomed. The crucial factor behind this development was the research activity of Justus von Liebig in Gießen. He established chemistry as an academic discipline and changed the focus of the subject to experimental basic research: that is, in addition to the scientific basis of chemistry, students would henceforth also learn about experimental work in the laboratory. In addition to the breakthrough innovations achieved through basic chemical research, the chemists who had been educated in this way made a crucial contribution to the rise and success of the paint industry.

Above all, Germany developed into an attractive innovation location for the newly-emerged chemicals sector, not least because the number of academically trained chemists increased here more than anywhere else in the world. During this period, seven paint factories were established in the valley of the River Wupper alone. Two of them still constitute the heart of the chemical and pharmaceutical industries in Germany today; Bayer and BASF are *global players* with over 100,000 employees each throughout the world and tens of billions in sales. The close association of research and the chemical industry shows that the researchers trained in the approach and methods of basic science can also contribute their knowledge and problem-solving skills to development and application in industrial settings.

2.2 The local dimension of knowledge dissemination in regional clusters

Today's pharmaceutical and biotechnology industries are current examples that illustrate the importance of basic research as a driving force of innovation and the basis of economic

[13] Gersbach, Hans, "Basic research and growth policy", in: *The New Economics of Technology Policy*, edited by Dominique Foray, 113–21, 2009.

development. Biotechnology itself was established through pioneering breakthroughs in modern molecular biology. The discovery of what is referred to as restriction enzymes, for example, had a crucial influence on subsequent drug development. Today, pharmaceutical biotechnology is very heavily reliant on existing basic research skills. The fact that the local dimension of the dissemination of knowledge plays a particularly important role in this process is already evident from the earliest history of biotechnology: *Genentech* and *Amgen*, the first pure biotech companies, were established in *California* in close proximity to *Stanford University* and the *University of California*, in *San Francisco* and *Berkeley*. The reasons for this proximity remain valid today although expertise can also be acquired internationally through patents and publications. For example, biological "tools" like plasmids, DNA sequences, and even microorganisms or animal and plant strains are exchanged between individual laboratories in different countries today.[14]

However, non-codified skills and knowledge, so-called *tacit knowledge*, are often of crucial importance in the biosciences, in general, and biotechnology, in particular. This kind of knowledge can only be transmitted in person and this is why biotechnology flourishes mainly in local or regional innovation environments or clusters, which must be connected, in turn, to international cutting-edge research networks. For this reason, in Germany, biotechnology is mainly located in cluster centres in Berlin, Cologne, Heidelberg and, of course, Munich, where it has access to an excellent environment characterised by internationally competitive research organisations and a correspondingly educated workforce. In Munich, for example, the majority of the companies working in this area came into being as start-up spin-offs from the Max Planck Institute of Biochemistry and the Gene Center Munich at the Ludwig-Maximilians-Universität (LMU).[15] Today, approximately 180 life science companies with around 20,000 employees form the economic heart of the Munich biotech cluster, which is among the absolute leaders in this field in Europe.[16]

As fostered by its federalist Basic Law and the accompanying organisational freedom accorded to the federal states, Germany can boast internationally visible regional innovation areas in numerous other key technology fields along with biotechnology.[17] Bavaria, Baden-Württemberg and Hesse together account for over half of all R&D expenditure in Germany.[18] In the area of renewable energies and information and communications technology (ICT), Bavaria and Baden-Württemberg are among the top ten regions in the world which have recorded the highest number of patent applications. In the case of renewable energies, Bavaria is even among the top five (after the USA, two regions of Japan and Korea). After Japan (Kanto region) and the USA (California), the highest number if ICT patent applications are already being made by the Chinese province of Guandong, which is located in the

[14] Korte, Martin, "Wie international ist die Wissenschaft?" In *Wettlauf ums Wissen. Außenwissenschaftspolitik im Zeitalter der Wissensrevolution*, herausgegeben von Georg Schütte, 166–175, 2008. http://pub.uni-bielefeld.de/publication/1861302 P.168

[15] Grande, Edgar and Robert Kaiser, "The Transformation of the German System of Innovation: The Case of Biotechnology", in: *Knowledge creation, diffusion, and use in innovation networks and knowledge clusters: a comparative systems approach across the United States, Europe, and Asia*. Greenwood Publishing Group, 2006.

[16] Kuhlmann, Stefan, "Forschungs- und Innovationssysteme im internationalen Wettbewerb", in: *Wettlauf ums Wissen: Außenwirtschaftspolitik im Zeitalter der Wissensrevolution*, herausgegeben von Georg Schütte. Berlin: Berlin University Press, 2008. P. 56

[17] Kuhlmann, Stefan, "Politisches System und Innovationssystem in 'postnationalen' Arenen", in: *Innovationspolitik in globalisierten Arenen*, edited by Klaus Grimmer, Stefan Kuhlmann, and Frieder Meyer-Krahmer, 11–39. VS Verlag für Sozialwissenschaften, 1999. http://link.springer.com/chapter/10.1007/978-3-663-10359-2_1 P. 14f.

[18] http://www.statistik-bw.de/veroeffentl/Monatshefte/essay.asp?xYear=2012&xMonth=01&eNr=04

Special Economic Zone of Shenzhen.[19] The example of China – as well as those of India and Brazil – shows that highly integrated innovation regions, which already excel in the context of the international competition, today can be found even in countries whose national research and innovation performance is comparatively average.[20]

2.3 Cutting-edge research gives rise to successful innovative milieus

Global technology leadership builds on pioneering knowledge. This is only generated in internationally-oriented, but locally-dense innovative milieus, which do not emerge in the absence of excellent basic research as their cornerstone.

This is also demonstrated by the example of Great Britain: the United Kingdom achieves economically positive effects through the location of globally leading business ventures in academic centres of excellence like Cambridge and Oxford, which extend far beyond the region in question and play an important role in the overall economy. In addition to traditional science and technology-based firms, these centres also attract service companies. It is an acknowledged fact that one or more top research institutes are always at the heart of such innovation clusters.[21] *Cambridge Science Park*, which arose in the environment of the university, is one of the most globally successful examples of this type of cluster. Based on the intellectual resources of the University of Cambridge, a unique environment for science-based start-ups emerged there; as a result, 8 percent of total European (!) expenditure in terms of risk capital for new businesses is concentrated in the small region around Cambridge.[22]

To facilitate the access to and personal interaction between their research and development staff and basic academic research, a series of multinational companies have also established their commercial research laboratories in direct proximity to the university's leading departments. Commercial technology development benefits from proximity to publicly funded research: for example, at two-thirds, the majority of American applications for industrial patents cite top publications that originate from publicly-funded cutting-edge research institutions in the USA.[23] As part of this process, successful companies look for the best research-intensive innovation locations: Toshiba and Microsoft, for example, have both invested in large research laboratories on-site in Cambridge. *Microsoft Research Cambridge* was Microsoft's first research laboratory outside its home campus in Redmond. Despite the

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19 During the period 2008-2010. Cf. Primi, Annalisa, "The Evolving Geography of Innovation: A Territorial Perspective", in: *The Global Innovation Index 2013: The Local Dynamics of Innovation*, herausgegeben von Soumitra Dutta, Bruno Lanvin, Insead, World Intellectual Property Organization, und Johnson Graduate School of Management (Cornell University), 69–78, 2013. http://globalinnovationindex.org/content.aspx?page=gii-full-report-2013 P. 72

20 Hollanders, Hugo, "Measuring Regional Innovation: A European Perspective", in: *The Global Innovation Index 2013: The Local Dynamics of Innovation*, edited by Soumitra Dutta, Bruno Lanvin, Insead, World Intellectual Property Organization, and Johnson Graduate School of Management (Cornell University), 79–85, 2013. http://globalinnovationindex.org/content.aspx?page=gii-full-report-2013 P. 80

21 Arthur, Michael and Wendy Piatt. "The economic impact of research conducted in Russell Group universities", 2010. P. 12

22 Salje, Ekhard K.H. "The race to the top: some insular comments on science policy". In *Wettlauf ums Wissen: Außenwirtschaftspolitik im Zeitalter der Wissensrevolution*, edited by Georg Schütte, 59–66. Berlin: Berlin University Press, 2008. P. 59

23 Narin, Francis, Kimberly S. Hamilton and Dominic Olivastro. "The increasing linkage between U.S. technology and public science". Research Policy 26, No. 3 (October 1997): 317–30. doi:10.1016/S0048-7333(97)00013-9.

emergence of numerous other company laboratories in Asia, India, the USA and Germany (Munich), the Cambridge laboratory remains one of the software manufacturer's most important and largest facilities. The world-renowned *University of Cambridge Computer Laboratory* had a decisive influence on the choice of location for the Microsoft laboratory.[24]

The *University of Oxford* is also an innovation nucleus of national importance for Great Britain: although (or precisely because) the university does not have a dedicated application orientation and has devoted itself to excellent basic research at world class level, it generates in excess of three times more university spin-offs than the average number for all British universities – and enjoys an extraordinarily high rate of success. The scientific excellence of the university is undisputed; it ensures this through the consistent development of its special interdisciplinary research centres (there are 14 biomedicine centres, one of the university's focal fields) and groups, which cooperate beyond traditional subject boundaries and also collaborate with the best academic and industrial partners, both locally and globally.[25]

Of course, German companies have long been availing of the innovative context of globally-leading research regions – including those located abroad. For example, in the area of medical technology, with its *Siemens Molecular Imaging* in Oxford, Siemens benefits from the university's leading global *expertise* in the life sciences. Other top German companies like Daimler and Bosch also avail of locally available expertise through their company research subsidiaries in international innovation locations. In *Silicon Valley*, for example, the companies seek the proximity of top universities like Stanford and Berkeley with a view to accessing important inspiration for their innovation projects throughout their global corporative alliance. The proximity to possibly lucrative foreign markets tends to be a more subordinate criterion when it comes to choosing locations.[26]

2.4 Dynamic innovation regions are developing throughout the world

The importance of basic research as the cornerstone of economic development has been recognised by many countries outside the G7. For example, Korea is already acknowledged as a high-tech producer in the area of information and communications technology, best known, perhaps, through the Samsung concern. However, the example of Samsung also shows that Korea has pursued a *close-follower* strategy in the high-tech sector, whereby innovative basic ideas were adopted from others, and gave rise to better and, at the same time, cheaper products. Because this role is being increasingly assumed by China – particularly in the area of communications technology - South Korea is beginning to follow a new direction. It is a declared aim of its government that the country will become an

[24] Arthur, Michael and Wendy Piatt. "The economic impact of research conducted in Russell Group universities", 2010. P. 12

[25] Lawton Smith, Helen and K. Ho. "Measuring the performance of Oxford University, Oxford Brookes University and the government laboratories' spin-off companies". *Research Policy* 35, No. 10 (2006): 1554–1568. P. 1558f.

[26] Expertenkommission Forschung und Innovation (EFI), Berlin, "Gutachten zu Forschung, Innovation und technologischer Leistungsfähigkeit Deutschlands 2012", 2012. http://hdl.handle.net/10419/58043 P. 27

independent *technology leader*. This can only be achieved through a greater focus on self-generated, pioneering knowledge from basic research.[27]

While applied and industrial research is very well positioned, basic research has been insufficiently developed in Korea up to now.[28] To enable the country to compete in this area in the future, Korea established the *Institute for Basic Research* (IBS) in 2012. The IBS is based on the model of the Max Planck Society and the Japanese RIKEN research institute and it is planned to develop it into one of the globally leading institutes for basic research. The Korean government intends to provide funding amounting to the equivalent of approximately EUR 31 billion for this purpose until 2017.[29] In this way, the IBS will form the cornerstone and nucleus of an entire innovation region, the so-called International Science and Business Belt.[30] Aside from the considerable additional expenditure involved in the development of the IBS and its planned 50 research centres, Korea's commitment to basic research is substantial. During its development phase, the IBS will have an annual budget of EUR 4.5 billion at its disposal. In comparison, with its current 83 institutes, the Max Planck Society has almost EUR 2 billion at its disposal annually.[31] Hence, even if Korea only honours its proposed commitment to the IBS in part, its research centres will be considerably better off than the institutes of the Max Planck Society, for example.

Thus, in addition to the established research locations in the USA and Great Britain, dynamic innovation regions are developing in Asia, India and South America. In the medium term, these will undoubtedly be of interest to companies that have carried out their research in Germany up to now and operate development laboratories here. What are the implications of such an analysis for Germany?

To continue to attract private-sector R&D investment, the German science system must also compete with Stanford, Oxford, Berkeley and other locations, for example through the targeted development of selected centres of excellence. The German Commission of Experts for Research and Innovation (Expertenkommission Forschung und Innovation, EFI) reported in 2010 that the R&D activities of German companies are increasingly being developed abroad. In its 2014 report, the EFI currently confirms that approximately one-third of research expenditure is made outside Germany.[32] This trend can be observed not only among sectors like the automotive industry that are seeking proximity to foreign markets; German industry also carries out research abroad in particularly promising and rapidly developing fields like pharmaceuticals, biotechnology and software, as well as areas like electronics,

[27] Park, Soo Bin, "South Korean research centre seeks place at the top". *Nature* (17 May 2012), doi:10.1038/nature.2012.10667.

[28] OECD, *OECD Reviews of Innovation Policy: Korea 2009*. Paris: Organisation for Economic Co-operation and Development, 2009. http://www.oecd-ilibrary.org/content/book/9789264067233-en P.15

[29] Paulus, Michael, "Südkorea: Globalisierung versus Tradition", in: *Die Internationale Hochschule: Strategien anderer Länder*, herausgegeben vom Deutscher Akademischer Austauschdienst, 72–78. Bielefeld: Bertelsmann, 2013. P.76

[30] Feder, Toni, "South Korea invests big in basic research", in: *Physics Today* 65, No. 10 (2012): 26–27. doi:10.1063/PT.3.1746.

[31] The total income of the MPG in 2012 was EUR 1.2 billion. Cf. 2012 Annual report of the Max Planck Society. http://www.mpg.de/7300568/2012

[32] Expertenkommission Forschung und Innovation (EFI), "Gutachten zu Forschung, Innovation und technologischer Leistungsfähigkeit Deutschlands 2014". P. 41 English version: "Research, Innovation and Technological Performance in Germany, Report 2010" (see http://www.e-fi.de/index.php?id=9&L=1)

telecommunications and electrochemicals. Whereas a shift in focus to Asia can be observed in the case of the latter sectors, the former tend to target top locations in the USA. If this development is sustained, it will have negative impacts on the innovation system in Germany in the long term. The cooperation between private-sector research and basic public research is only worthwhile for the economy if it has access to competitive structures and personnel throughout the world.[33] Germany must also offer this in the long term if it wishes to continue to attract and retain companies as R&D investors.

3. Global Excellence Requires National Excellence

3.1 Basing performance on global standards

For Germany as a research location, this increasingly globalised, knowledge-based 'global society' means greater competition between locations. This competition is intensifying on all levels; and one particularly important level is that of cutting-edge basic research. This is the key element of the knowledge infrastructure of all innovation systems; it has the appeal that makes a location broadly attractive to scientific personnel and enables the establishment of connections with international innovation networks. Therefore, the targeted establishment and development of national capacities for basic cutting-edge research is the crucial arena for the design of national and regional research policies. In view of the dynamics of international competition, this is the only way that the performance of Germany's own science system – and ultimately also that of its economy – can be improved.

Even if top performance at national level also forms the basis for international competition, a top national position does not simultaneously guarantee international success. In the international competition context, the universities are effectively in competition with establishments which, like *Harvard* and *Stanford*, for example, have far more resources and a traditional culture of excellence. The latter are very widely represented on the level of cutting-edge research and have long been integrated in international excellence networks in all important disciplines, both in relation to teaching and research.[34] To be able to participate in such networks, a university or research institution must have already attained a very high level of performance. Nevertheless, the global competitiveness of a research location stands and falls with the financial and organisational possibilities provided by the national regulatory framework.[35] Hence, a national culture of excellence is the necessary condition for international success. The German science system will only achieve sufficient global success, however, if it directs its decisions relating to financial and organisational reform at the development of such a culture of excellence based on global standards.

With regard to the financial dimension, the German science system has developed extremely positively in the past. According to the statistics compiled by the Stifterverband für die

[33] Expertenkommission Forschung und Innovation (EFI). "Gutachten zu Forschung, Innovation und technologischer Leistungsfähigkeit Deutschlands 2010", p. 39 English version: see above

[34] Horta, Hugo, "Global and National Prominent Universities: Internationalization, Competitiveness and the Role of the State", in: *Higher Education* 58, No. 3 (1. September 2009): 387–405. doi:10.1007/s10734-009-9201-5. P. 389.

[35] Schütte, Georg, Hrsg. *Wettlauf ums Wissen: Außenwirtschaftspolitik im Zeitalter der Wissensrevolution*. Berlin: Berlin University Press, 2008. P. 235

Deutsche Wissenschaft (the German business community's agency for the German science system), the European Union objective of three percent of gross domestic product (GDP) in expenditure for research and development is already in sight: in 2011, 2.88 percent of GDP was invested in R&D across all sectors in Germany.[36] This places Germany significantly above the average for the OECD states and in the top third with the highest investment in R&D. However, other highly-developed states have already well exceeded the 3 percent line: in 2011, Switzerland, Denmark, Japan, Korea, Finland and Israel were already investing a higher percentage of GDP in research and development than Germany.[37] Thus this positive investment trend in Germany must be sustained if we wish to continue to compete successfully with other locations. Although China still lags behind the average for all OECD countries (2.38 percent of GDP in 2010)[38] in relative terms with its expenditure of 1.76 percent of GDP on R&D, in absolute terms, the People's Republic has been second only to the USA in relation to spending on research and development since 2009. If, as is already expected, China overtakes the USA in its gross national product by 2020, it is highly probable that it will also take the lead in relation to research expenditure.

In view of these developments, as requested by the Commission of Experts for Research and Innovation, the German target for R&D expenditure should be increased to at least 3.5 percent of GDP. Because basic research as a key element of the innovation structure is reliant on public funding, the responsibility here lies with the federal and federal state authorities, in particular. Of course, this applies equally to basic research in the university and non-university sectors. In view of technological progress and expected long-term demographic development, such a requirement is not a vested interest of science by a long chalk. Germany must remain attractive to talented people from abroad, be able to educate them and enable them to carry out research in corresponding innovative fields.

Fortunately, this objective has been shared by politicians in recent years. Thanks to the political prioritisation of research and development, constant increases in public expenditure on R&D have been made possible. This positive political climate has also had the effect of attracting private R&D investment: the 0.43 percent increase in expenditure in the period from 2000 to 2011 was divided almost equally between the private sector and the state; in 2011, private-sector expenditure amounted to 1.94 percent of GDP. Meanwhile, the state invested 0.52 percent of GDP in the universities and 0.42 percent in all of the publicly-funded research institutions. In addition to the non-university research institutions like the Helmholtz Association and Leibniz Association, this also includes the specialised federal and federal state research institutions and a not insignificant number of non-associated federal state research institutions.[39] If German science would like to successfully measure up to global standards, public research finance policy must also remain a long-term political priority. Moreover, it is not merely a matter of finance: far more important is the provision of stable general conditions, on which science can rely in the long term. The political constellation of a

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[36] Stifterverband für die Deutsche Wissenschaft, "FuE-facts 2013" *FuE-facts - Zahlen & Fakten aus der Wissenschaftsstatistik GmbH im Stifterverband* Nr. Februar (2013). http://www.stifterverband.org/statistik_und_analysen/wissenschaftsstatistik/publikationen/fue_facts/fue_facts_2013-01.pdf. P. 4

[37] OECD, "Key Figures". *Main Science and Technology Indicators*, *Volume 2012 Issue 2*, (18 February 2013). doi:10.1787/msti-v2012-2-4-en.

[38] OECD (2013), "International Comparisons", in *Main Science and Technology Indicators, Volume 2012 Issue 2*, OECD Publishing. http://dx.doi.org/10.1787/msti-v2012-2-5-en

[39] Stifterverband für die Deutsche Wissenschaft, "FuE-facts 2013".

Grand Coalition (between the Christian Democrats and Social Democrats), in particular, would now have the opportunity to organise the legal structures on the basis of the challenges to be faced in the future in a way that guarantees long-term success.

3.2 Maintaining the dynamics of the Excellence Initiative

Germany's positive development in the area of research funding was accompanied by a drive for the expansion of the organisational possibilities within the science system: the Excellence Initiative, which was established in 2005, offered German universities a perspective for the development of sustainable excellence structures for the first time. Based on this initiative, using financial incentives the universities were facilitated in improving their positioning for the future through strategy processes and profile development in the context of both national and international competition. This marked the initiation of a long-needed process of performance differentiation of German university research in the face of growing international competition.

The German university landscape had previously been characterised by a very high level of performance across the board, including when compared with the international context: prior to the Excellence Initiative, there were, of course, universities in Germany that stood out from the crowd through their internationally visible research achievements. However, even the top German universities failed to attain a place at the top of the global scientific league: the downside of the broadness of the achievements within Germany's university system was the implicit suggestion that all universities must be the same and that there should be no differences in performance per se.

For this reason, for many decades it was almost impossible for the German universities to form centres of excellence in research and teaching so as to establish connections with top international locations. This legacy of university expansion in the old Federal Republic, which had the sole aim of developing universities horizontally (university places for everyone) instead of also – competitively – vertically (excellence), was finally overcome with the Excellence Initiative.[40]

However, penetrating to the top of the global research elite requires staying power. Taking into account the history of the development of many of its institutes, for example the Fritz Haber Institute in Berlin, the Max Planck Society can look back on over 100 years' experience in the area of cutting-edge research. The establishment and development of excellence structures requires time and money. However, the establishment of aggregated scientific reputation, which is valid at a high level for an entire university, i.e. for almost all faculties, requires an even longer development timeframe. Globally recognised top institutions like *Oxford* and *Cambridge* enjoy several hundred years of scientific tradition. This kind of tradition also exists at German universities. However, in the past these were strongly hampered in their strategic action scope by the difficult balancing act between elite and general education.

[40] Wintermantel, Margret, "Profilbildung und Exzellenzinitiative: Perspektiven der Differenzierung im deutschen Hochschulsystem": in Exzellente Wissenschaft: Das Problem, der Diskurs, das Programm und die Folgen, herausgegeben von Stefan Hornbostel, Dagmar Simon, und Saskia Heise. IFQ, 2008. P.93f.

For this reason, the additional funding provided by the Excellence Initiative has proved essential for the development of the strategic capacity of the universities involved and have triggered the dynamic development of cutting-edge university research. The impacts of the Initiative have been very positively received, particularly abroad.[41] In terms of effective foreign science-policy marketing, the "Excellence universities" are already being perceived as such by other top international universities. However, this development is far from complete and the Excellence Initiative is due to end in 2017. To develop individual locations that attract the best graduates, experts and scientists, it will be necessary to continue the process of the vertical differentiation of the universities started by the Excellence Initiative. As the experience gained up to now has shown, the institutes of the Max Planck Society can make a significant contribution to the development of cutting-edge university research centres. The Max Planck institutes are already the central partners of the universities in many university locations, be it in the area of ageing research in Cologne (Max Planck Institute for Biology of Ageing) or in the field of neuroscience in Tübingen (Max Planck Institute for Biological Cybernetics and the Max Planck Institute for Intelligent Systems).

The performance differentiation of the universities must not have a negative effect on general academic education, however. The strengths of our complementary teaching and research landscape must be conserved. To this end, the universities must be facilitated in maintaining this level, even in the face of increasing student numbers, through greater basic funding. Beyond the conservation of the broad basis, what is lacking is the presence of a German university at the top of the global science league. The positioning of one or more universities at the top of this league can only succeed through scientific competition. Thus, both the idea of competition and the principle of cutting-edge scientific performance must also be further pursued with the consolidation of the structures established as part of the Excellence Initiative.

An effective balance between the necessary continuity and openness in the competition for funding that ensures quality must also be guaranteed in future. Scientific excellence cannot be determined politically and requires continuous evaluation by science itself. "Excellence inflation" can only be effectively counteracted through independent science-led quality assurance mechanisms. In the case of the Max Planck Society, for example, the internationally composed Scientific Advisory Boards guarantee the thorough evaluation of the Max Planck institutes. Of the current 800-plus Scientific Advisory Board members, over one-fifth come from top institutions abroad, including several Nobel laureates. The Scientific Advisory Boards do not evaluate applications but research achievements over a two- to three-year cycle. This reduces the danger that high-risk innovations will fail when measured using mainstream standards.[42] Critical assessment by renowned peers ensures the quality of the research carried out at the Max Planck institutes at a globally competitive level. This objective must also be to the fore in the evaluation of possible follow-up structures for the Excellence Initiative. However, constant evaluation or application pressure must also be avoided along with the cementing of *closed-shop* structures.

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[41] Macilwain, Colin. "Excellence, Ja, Elitism, Non", *Science* 338, No. 6107 (11. Februar 2012): 596–599. doi:10.1126/science.338.6107.596.

[42] Kant, Horst and Jürgen Renn, "Forschungserfolge und ihre Voraussetzungen in der Kaiser-Wilhelm-Gesellschaft und Max-Planck-Gesellschaft", in: *Kreativität in der Forschung - Wissenschaftsforschung Jahrbuch 2012*, herausgegeben von Thomas Heinze, Heinrich Parthey, Günther Spur und Rüdiger Wink, 141–155. Berlin: wvb, Wiss. Verl., 2013. P. 154.

It must continue to be possible to rise, as well as fall: for this reason alone, all Excellence efforts must build on our existing differentiated overall system. German cutting-edge research needs this strong performance basis to be able to catch up – also on the part of individual German universities – with successful top global institutions like the *University of Oxford* and the *University of California, Berkeley* in the areas of research capacity and international visibility in the long term.

3.3 Focusing on sustainable excellence

In many cases, politicians are unfortunately unaware of how lengthy, complex and expensive a process it is to establish new top research institutions or develop existing ones. The global competition and increasingly rapid pace of technical progress have driven the cost of top research to levels today that would have been inconceivable only ten years ago.

The development of substantial research excellence requires considerable financial expenditure if this research should be capable of competing at international level. Top universities require high levels of funding in the long term to be able to recruit the best scientists and students and to be able to provide the infrastructure necessary for a competitive research environment and attractive courses at the highest level.[43] Investments, be they in universities or non-university research institutions, always generate long-term financial commitments. For this reason, the long-term stability of the financing is particularly important.[44]

The annual operation of an institution that could measure up to the best of the *Ivy League* institutions would cost up to USD 2 billion. In the USA, these institutions obtain around 20 percent of this sum from tax revenues and 30 to 40 percent from competitive third-party funding. This third-party funding also includes a high level of state funding for the promotion of research. When the funding sources of a typical 'federal university' like the Swiss Federal Institute of Technology Lausanne (EPFL) are compared to those of the American *Ivy League* colleges, the far higher proportion of public funding included in the former's budget is striking: in 2012, 68 percent of the EPFL's budget came from the Swiss federal state, 28 percent from third-party sources (of which, again, over half originated from the state) and only barely four percent from tuition fees.[45]

Approximately 30 American universities have a budget of at least USD 2 billion or more. In 2012, *Harvard University* actually reached a total budget of USD 4.24 billion. No European university has been able to match such finance volumes up to now. These universities are among the most successful in the world and, accordingly, they top the international ranking lists. Even if their funding levels do not guarantee success, the level of the resources available is a key determinant of their research success and the global scientific reputation

[43] Altbach, Philip G, "The Past, Present, and Future of the Research University", in: *The Road to Academic Excellence the Making of World-Class Research Universities*, edited by Philip G. Altbach and Jamil Salmi. Washington, DC: The World Bank, 2011. http://public.eblib.com/EBLPublic/PublicView.do?ptiID=787639 p. 12

[44] Mohrman, Kathryn, Wanhua Ma, and David Baker. "The Research University in Transition: The Emerging Global Model". *Higher Education Policy* 21, No. 1 (3 January 2008): 5–27. doi:10.1057/palgrave.hep.8300175. P. 6

[45] Cf. Annual Report of the EPFL, p. 74 https://documents.epfl.ch/groups/e/ep/epfl-unit/www/rapport/EPFL-annual-report-2012.pdf

built on it.[46] In addition, globally-leading non-university research institutes also exist in the United States, for example the *California Institute of Technology* and the *Scripps Research Institute.*

The institutions in Europe that enjoy similarly high levels of financial resources, for example the ETH Zurich (EUR 1.2 billion = USD 1.64 billion) and the *University of Oxford* (EUR 1.23 billion = USD 1.68 billion), are among the few that feature among the America-dominated top 20 in various rankings. In terms of German institutions, only the Max Planck Society features regularly among the top five in the various rankings; thanks to a budget of almost USD 2.5 billion in 2013, the latter is able to position its outstanding research institutions on a par with the best in the world.[47] As is also the case with the top American universities, which like *Harvard* and *Stanford* build on long-established structures of cutting-edge scientific performance, money alone does not form the basis of scientific performance and achievement.

For example, the trust of society and politicians in the efficacy of its scientific independence enables the Max Planck Society to push the boundaries of knowledge in areas of basic research, in which the immediate economic purpose of such knowledge may only become clear at a much later stage. This is the only way, however, that the breakthrough innovations, which science, society and the economy require to meet urgent challenges like the energy transition and demographic change can arise.

Compared with the commitments made by other countries, based on its most recent federal budget of EUR 310 billion, Germany could definitely afford to fund more organisations that can carry out excellent cutting-edge research on a global scale in addition to the Max Planck Society. For example, Singapore relies entirely on science and innovation to guarantee the prosperity of its small state: in 2013, the *National University of Singapore* had a budget of USD 1.75 billion which was provided from a state budget that does not even represent ten percent of that of Germany![48] Of the one million in habitants in Singapore, 5,500 people work in future-oriented sectors of research and development. This places the small city-state in second position behind Sweden, where 6,000 people per million inhabitants are employed in these areas.[49]

Europe must also focus on scientific excellence and needs more top research institutions that make regionally-concentrated cluster locations broadly attractive to foreign scientific personnel and facilitate access to international innovation networks. The European Union has recognised this and through the person-centred *grants* allocated by the *European Research Council* aims to attract such highly-talented scientific personnel from all over the world to Europe. Science, like the economy, is promoted in this way, and improves economic

[46] Mohrman et al, "The Research University in Transition", p. 11

[47] Based on its specific mission, the MPG receives 78 percent of its funding from the state and Länder (federal states), almost 16 percent from third-party sources, and six percent from private foundation sources and its own revenues (e.g. licences).

[48] Of which, almost USD 1 billion came from the state. Cf. 2013 Annual Report of the National University of Singapore, p. 68. http://www.nus.edu.sg/annualreport/2013/upload/nus-annualreport-2013.pdf

[49] Mukherjee, Hena and Poh Kam Wong, "The National University of Singapore and the University of Malaya: Common Roots and Different Paths", in: *The Road to Academic Excellence the Making of World-class Research Universities*, edited by Philip G Altbach and Jamil Salmi, 129–166. Washington, DC: The World Bank, 2011. http://public.eblib.com/EBLPublic/PublicView.do?ptiID=787639. P. 155

competitiveness both directly and indirectly.[50] In the long term, university institutions are also needed in Germany which, like the Max Planck Society, *Oxford University*, the EPFL and the ETHZ can cooperate on an equal level with top American institutions like *Berkeley*, *Stanford* and *MIT*, and can attract top scientists to Germany.

In addition to the long-term perspective of the development of perhaps three to five top university locations in Germany, more regional clusters with certain specialised thematic profiles will also emerge. Every location does not, of course need a top research institute of the size of *MIT*. The highly-specialised research institutes of the Max Planck Society already increase the international visibility of many locations today. In the context of a future multipolar 'global science system', regions, federal states and municipal conurbation centres will also be able to gain access to the global scientific elite with the help of reasonable but targeted financial expenditure.[51]

3.4 The emerging global model of successful research institutions

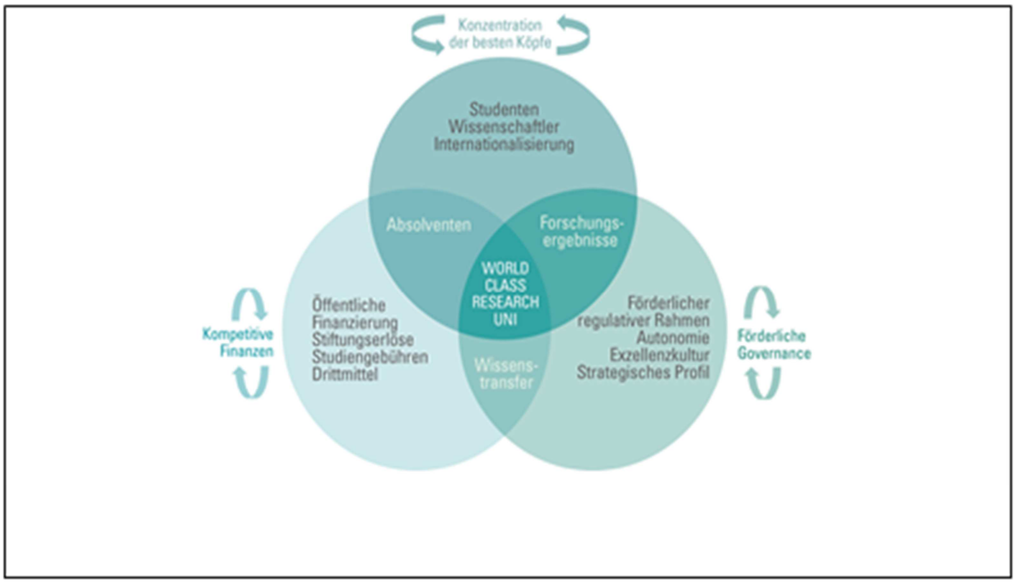

Figure 2: Characteristics of a *World-Class Research University*. Source: Altbach 2011.[52]

[50] "Research Policy: How to Build Science Capacity", Nature 490, No. 7420 (18 October 2012): 331–334. doi:10.1038/490331a.

[51] Rogers Hollingsworth J., Karl H. Müller and Ellen Jane Hollingsworth. "China: The End of the Science Superpowers," *Nature* 454, No. 7203 (24 July 2008): 412–413. doi:10.1038/454412a P. 332

[52] Altbach, Philip G, "The Past, Present, and Future of the Research University", in: *The Road to Academic Excellence the Making of World-class Research Universities*, edited by Philip G. Altbach and Jamil Salmi. Washington, DC: The World Bank, 2011. http://public.eblib.com/EBLPublic/PublicView.do?ptiID=787639

What exactly are the characteristics of the top global research institutes? If one considers the top global universities from the main rankings (be it *Shanghai*, *THE* or *QST*), it becomes obvious that all of those featured in the rankings are globally renowned research universities. Irrespective of the structural differences in the varying global university systems, research universities are understood as the central institutions of a science system that carry out most of a country's free basic research and are responsible for post-graduate education. Far from all universities in most other countries are research universities: in the strongly differentiated system of third-level education in the USA, around 150 out of 4,800 institutions are considered as research universities; the corresponding figure in India is only 10 out of 18,000 and China has at most 100 research universities among its 5,000 third-level education institutes.[53]

The importance of such institutions for the economies involved in the global competition is undisputed. As the nucleus of the development of regional innovation clusters, they form the basis for positive social and economic development and the securing of already established prosperity. For this reason, with the rapid development of not only the BRICK states since the end of the East-West conflict, it is possible to observe the spread of the model of the research universities to states that were not previously competitive in the context of science. Renowned university research experts like Philip Altbach identify this process as one of increased "internationalisation" in the sense of the global export of the model of the research university. Thus, this form of institution is spreading beyond the traditional academic centres in Europe and North America to developing and newly industrialised countries.[54]

However, orientation as a research university alone does not qualify as a criterion for gaining a place at the top of the global university league. All American research universities do not, of course, feature among global academic leaders, not to mention all of the aforementioned Indian and Chinese institutions.

The few dozen or so institutions that can count themselves as members of the global university elite form a special sub-group of the research universities throughout the world – the *world class research universities*. They adopt an emerging transnational structural model in their orientation: the central characteristics of this '*emerging global model*' include an international alignment, above-average research performance, global recruitment of the best scientists and globally oriented cooperation with similar institutions.[55] Budgetary autonomy and research freedom as part of a promotional *governance* approach form the basic prerequisite for successful scientific operation. In this way, thanks to their outstanding performance in the area of basic research, the *world class research universities* access completely knew scientific topics and generate genuinely *new* knowledge. Through successful technology transfer strategies and their special role in both local and regional innovation milieus, breakthrough innovations of both social and economic importance emerge through the application of their research.

[53] Ibid, p. 11f.

[54] Liu, N. C., Qi Wang and Ying Cheng, *Paths to a World-Class University: Lessons from Practices and Experiences [from papers presented at The Third International Conference on World-Class Universities, held in November 2009 in Shanghai, China]*. Springer, 2011.

[55] Mohrman, Kathryn, Wanhua Ma and David Baker, "The Research University in Transition: The Emerging Global Model", in: *Higher Education Policy* 21, No. 1 (3 January 2008): 5–27. doi:10.1057/palgrave.hep.8300175. P. 5

All successful *world class research universities* are supported in their specific mission by a promotional regulatory framework; as an integral component of a differentiated science system they stand at the apex of the academic hierarchy.[56] This special place in the overall system is ensured through the guaranteeing of scientific and budgetary autonomy and corresponding financial resources. In addition to their research performance, the *world class university* institutions justify this special position through the constant, competition-oriented optimisation of their strategic profile. The central focus of this profile is a general culture of excellence that incorporates recruitment, research, teaching and cooperations.

The majority of the existing *world class research universities* are top American universities; the rest are mostly modelled on the most successful US universities. This practice can be observed in particular among countries that would like to establish or develop top locations to increase their international competitiveness and visibility. In this way, institutions like *Harvard*, *Stanford*, *Berkeley*, *MIT* and *Caltech* develop enormous structural and also thematic influence on the global science system: through their strong scientific performance and the accompanying attractiveness to the best scientists from all over the world, a self-perpetuating concentration of the best minds arises at these top universities. Based on a dynamic recruitment policy with adequate financial backing, promising research topics can be pursued at an early stage and strategically developed. Newly-appointed professors from all over the world bring already top-quality scientific networks with them to these universities.

The scientists at the *world class research universities* are themselves cooperation partners who are in demand at global level. The international dimension is particularly important here as, with the increasing specialisation of disciplines, cooperation projects must be established with the complementary and most suitable specialists throughout the world.[57]

Without the corresponding research performance and the resulting reputation, an institution will not succeed in working with the top scientist or establishing ties with them. Without this international orientation, that is if the national standard prevails in relation to both competition and collaboration, it is impossible to successfully establish connections with the network of top global research institutions.

This can only be achieved if the research capacity can keep pace with the comparative international level: to be able to participate in the international innovation networks of the global knowledge economy, a country needs at least one research institution that has connections with the top and can keep pace with the level of the world class research universities.[58] This is the only way that the best minds can be attracted on the different career levels and that strategic networks can be developed through targeted internationalisation measures.

[56] Altbach "The Past, Present, and Future of the Research University" 2011. P. 24

[57] Altbach, "The Past, Present, and Future of the Research University" 2011, p. 19f

[58] Deem, Rosemary, Ka Ho Mok and Lisa Lucas, "Transforming Higher Education in Whose Image? Exploring the Concept of the 'World-Class' University in Europe and Asia", in: *Higher Education Policy* 21, No. 1 (2008): 83–97. doi:10.1057/palgrave.hep.8300179.

4. Developing a Global Network: Strategic Internationalisation

4.1 Network nodes attract the best minds

Scientific performance is crucial when it comes to participation in international collaborations. Hence, the fact that the number of publications arising through cooperation is rising, a steady increase can be observed in the number and diversity of the international partners involved in such collaborative ventures and, moreover, the spatial distances, over which such projects take place are also growing, must also be explained in the context of globalised scientific competition.[59] Ideally, of course, the spatially closest, best, that is scientifically most excellent, research partner is selected for cooperative ventures. Naturally, scientific excellence and the suitability of the match in terms of scientific perspective are always the decisive factor here. For this reason, in an increasingly globalised and differentiated global science system, distances, even extensive ones, will always be overcome in the quest for the best research partners.

Moreover, scientists with outstanding scientific reputations often act as the nodes in scientific networks. In the life and technical sciences, in particular, they have important non-codified skills and specific *tacit knowledge* that renders them particularly interesting as cooperation partners – also for young researchers.[60]

Junior scientists will always try to complete stages in their research at the institutions which excel in their subjects. These phases are usually among the most productive, which is why research institutions throughout the world are interested in attracting the best candidates from an international pool of applicants at an early age. Cross-border exchange has always existed in this regard; however, it has now been intensified and accelerated to a hitherto unprecedented level through globalisation. The scale and volume of mobility from outside Europe and the United States to these attractive research markets did not exist in the past: the mobility of academics has already enabled the first truly global labour market to emerge.[61] In view of the expected demographic development, an advantageous position in this global labour market is a matter of urgency, particularly for Europe: if current development trends continue, in 2040, 40 percent of all graduates from third-level institutions in the G20 area will have been educated in China and India. The USA and EU *combined* will only contribute one-quarter of candidates to the global graduate market.[62]

[59] Waltman, Ludo, Robert J.W. Tijssen and Nees Jan van Eck, "Globalisation of science in kilometres": in *Journal of Informetrics* 5, No. 4 (October 2011): 574–582. doi:10.1016/j.joi.2011.05.003.

[60] Wagner, Caroline S. and Loet Leydesdorff, "Network structure, self-organization, and the growth of international collaboration in science", in: *Research Policy* 34, No. 10 (December 2005): 1608–1618. doi:10.1016/j.respol.2005.08.002. P. 1615

[61] Salje, Ekhard K.H, "The race to the top: some insular comments on science policy", in: *Wettlauf ums Wissen: Außenwirtschaftspolitik im Zeitalter der Wissensrevolution*, edited by Georg Schütte, 59–66. Berlin: Berlin University Press, 2008. P. 62

[62] Organisation for Economic Cooperation and Development, *How Is the Global Talent Pool Changing?,* Vol. 5. Education Indicators in Focus. Paris: OECD Publishing, 2012. http://www.oecd.org/edu/50495363.pdf.

Especially the increased mobility of knowledge holders renders the exploitation and organisation of location-specific structural *attractors* all the more necessary.[63] Excellent basic research assumes an important role here. This has been confirmed not least by the establishment of the *European Research Council* (ERC). The example of the ERC shows that the scientific performance and attractiveness of a research institution are crucial when it comes to attracting outstanding scientists: because the *grants* are person-centred, the *grantees* usually opt for the best scientific nodes for their work. Therefore, in addition to the French *Centre national de la recherche scientifique* (CNRS), which is almost twice the size of the Max Planck Society, and outstanding research universities like Oxford, Cambridge and the ETH Zurich, the MPG was in third position when it came to receiving the most ERC grants since 2007. The former are not only top of the academic league in their own countries, but also form part of the *world class research universities* in the international context and hence fulfil a corresponding node function.

4.2 Dropping anchor abroad – Examples of successful initiatives

The American top universities have long been market-oriented through the tuition fees system. And the market for university education has long been globalised. Although, for example, the *Ivy League* universities have the power to attract students and scientists to the USA from all over the world with their superb American campuses alone, they do not rest on their laurels in this regard and engage in global networking: of the group of top American universities, *Yale University* was the first to establish an *undergraduate campus* outside the USA in 2011. The *Yale-NUS College* in Singapore is a joint project with the *National University of Singapore* (NUS). August 2013 was the first year's students embarked on their studies.[64] The interests of both sides are clear: while *Yale University* is expanding locally in a lucrative, growing education market, Singapore has long been trying to increase its profile in Europe as an education and innovation location and to attract Chinese, Japanese and Korean students to study there. With the help of the 'Yale trademark', it can target these students from the region directly.

An increasing trend for students to study in their home country is emerging in Korea, but also in China and the Middle East. For this reason, *Stanford University*, *Johns Hopkins* and *New York University* are represented in China, for example. A presence in growing innovation markets can prove worthwhile, not only for universities but also for research institutions from other countries. The *Massachusetts Institute of Technology*, for example, is forging a special path in this regard: it does not build up any direct campus subsidiaries outside the USA but establishes more partnerships with locations in dynamic innovation regions. The aim is to establish a global network of institutions that share the excellence principles and specific scientific *governance* of *MIT*. For this reason, *MIT* scientists help other research institutions that would like to base themselves on the *MIT* model.

MIT is currently supporting the establishment of a graduate institution with the *Masdar Institute* in Abu Dabi.[65] In Singapore, *MIT* is providing capacity building in the context of a

[63] Kuhlmann, Stefan, "Forschungs- und Innovationssysteme im internationalen Wettbewerb", in: *Wettlauf ums Wissen: Außenwirtschaftspolitik im Zeitalter der Wissensrevolution*, edited Georg Schütte, 52–58. Berlin: Berlin University Press, 2008.

[64] http://www.thecrimson.com/article/2012/5/24/international-harvard-yale-singapore/

[65] http://www.masdar.ac.ae/about-us/mit-partnership

cooperative effort with the newly-established *Singapore University of Technology and Design*.[66]

Both institutions advertise directly with the reference "*in collaboration with MIT*". Apart from the fact that MIT is well paid for these collaborative ventures, it is also increasing its profile through such partnerships. In the long term, the commitment to newly emerging innovation markets ultimately serves the purpose of attracting top scientists and academics to the *MIT* through such networks.

Universities that established themselves at international level at an early stage have enjoyed a competitive advantage over others up to now – be it because they are at home in internationally leading science countries, because they have more financial resources at their disposal or because they have simply engaged in corresponding internationalisation activities at an earlier stage.

The educational quality offered by German universities is also highly appreciated in the emerging education markets throughout the world: the RWTH Aachen has been acting as guardian in the context of a structured partnership with the Sultanate of Oman for the development of the *German University of Technology* in Oman (*GUtech*) since 2007. The RWTH is supporting *GUtech* in the establishment and development and establishment of courses and the development of research activities and a quality management system based on German standards. The RWTH also has a liaison office in China to facilitate contact with Chinese students and scientists. The Technische Universität München (TUM), which has offices in São Paulo, Cairo, Beijing, Mumbai and Singapore, is also boosting its internationalisation by establishing a presence in important research locations.

However, *Yale, Harvard, MIT* and *Cambridge* are the universities that embody the model of the 'world class universities' – that is leading *research universities* by international standards. This is a status that many other universities would like to achieve. Universities in Asia and the Arab region are making therefore considerable efforts to associate their universities with the 'world class university' brand. Given the increasing competition between the knowledge economies and the scarcity of talented personnel, this highlights the importance of being able to play in the scientific champion's league for research institutions.[67]

4.3 The example of the Max Planck Society

As measured by the various wide-ranging rankings, based on the aforementioned criteria, no German university can currently be described as a *world class research university*.[68] The validity of individual performance indexes may be disputable; however, the political power of ranking lists cannot be dismissed out of hand.[69]

[66] http://www.sutd.edu.sg/mit_collaboration.aspx

[67] Horta, Hugo, "Global and National Prominent Universities: Internationalization, Competitiveness and the Role of the State", in: *Higher Education* 58, No. 3 (1 September 2009): 387–405. doi:10.1007/s10734-009-9201-5. P. 389

[68] In the current *Academic Ranking of World Universities 2013*, at 50th place, the Technische Universität München achieves the best ranking among German universities. Only Heidelberg (ranked 54), Ludwigs-Maximilian-Universität München (ranked 61) and Freiburg (ranked 100) feature in the top 100. Cf. http://www.shanghairanking.com/World-University-Rankings-2013/Germany.html

[69] Hazelkorn, Ellen, *Rankings and the Reshaping of Higher Education: The Battle for World-class Excellence*. Houndmills, Basingstoke, Hampshire; New York: Palgrave Macmillan, 2011. P. 160

The vast supply of very different providers with equally diverse rankings demonstrates one thing in particular: the growing demand. The global elite of tomorrow is increasingly influenced by such indexes. The *Ivy League* universities enhance their reputation among potential students not least on the basis of a 'brand promise' for the professional careers of their graduates.[70] In Germany too, the eleven "Excellence Universities" selected by the German Council of Science and Humanities and the German Research Foundation (DFG) have been able to observe an increase in their appeal to potential students at home and abroad.

German universities are absolutely world class in individual research fields. However, none of them presents a performance spectrum comparable to that of the best *world class research universities*. Up to now, the Max Planck Society is the only institution in Germany that can successfully align itself with the research performance of the *world class research universities* across its entire disciplinary spectrum.

If the its research performance is measured solely on the basis of the quality and quantity of its publications, for example, the Max Planck Society can be found among the five globally leading institutions[71] in the *Nature Publishing Group*'s ranking.[72] If the criteria of the so-called "*Shanghai Ranking*"[73] were to be applied to the Max Planck Society, it would also be included in the top five group. However, *Shanghai Jiao Tong University*'s "*Academic Ranking of World Universities*" only compares universities and post-graduate universities.

The Max Planck Society does not have the status of a post-graduate university. In cooperation with the German universities, it provides scientific education for post-graduates on the doctoral track. In addition to engaging in the education of junior scientists, *together* with *Harvard University* and *Rockefeller University* for post-graduates, it shares the main characteristics of a world class research university. However, due to its small overall size compared to Harvard, its decentralised structure and the particular organisation of its institutes, it also differs from such institutions.

The 83 research institutes of the Max Planck Society are not concentrated locally on a single campus but are distributed among approximately 30 locations throughout Germany and five locations abroad. This has disadvantages. For example, the shared use of infrastructure is only possible in very few cases. Moreover, the wider intellectual environment of the Max Planck Society as a whole cannot be identified with a particular location.

Constant exchange and interaction – in particular through the process of scientific renewal of the entire Society – are guaranteed through a tried-and-tested system of scientific self-

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[70] Rühle, Alex. "Harvard University: Weltgeist als Marke", *sueddeutsche.de*, 17 May 2010, "Karriere" section. http://www.sueddeutsche.de/karriere/harvard-university-weltgeist-als-marke-1.571233.

[71] The *Nature Publishing Group Nature Asia-Pacific* ranking is based on the number of publications in the publishing group's journals (e.g. *Nature, Cell Research* and *The EMBO Journal*). Only "*primary research papers that were published as 'Articles, Letters and Brief Communications"* are counted. In addition to the total number of papers, the number of papers is specified for each institution, in which it is taken into account how many other institutions were involved in a paper (*corrected counts*).

[72] In addition to the MPG, it also includes Harvard, Stanford, MIT and all of the American NIH institutes which are counted as a single unit. Cf. http://www.natureasia.com/en/publishing-index/global/

[73] http://www.shanghairanking.com/aboutarwu.html

administration in the interaction of the three Sections of the Max Planck Society.[74] The decentralised structure and governance of the Max Planck Society and the specific organisation of its institutes offer many advantages, not only in relation to internationalisation.

Due to their relative smallness, the Max Planck Society's medium-sized, interdisciplinary research institutes are accustomed to integrating themselves into the local scientific environment of their individual locations. At the same time, they also engage in close cooperation with the top institutes and specialised colleagues throughout the world. Numerous theoretical and empirical research studies indicate that such highly-networked, comparatively small and flexible research units that enjoy a high level of scientific autonomy offer the greatest potential for the discovery of breakthrough innovations.[75] In this way, they can constitute the scientific core of their environment.

In addition, the Max Planck Society is generally open to the translation of the results of basic research to application. Greater activity and numerous successes in the area of technology transfer in recent years have shown that the Max Planck Institutes can also make important contributions to the development of innovation clusters.

Other countries have recognised this. In the context of an international comparison, many view the organisation of the Max Planck Society in small, flexible research units as a successful model.[76] In particular, countries that are only now in the process of developing top research structures are expressing great interest in the MPG's specific knowledge-driven *governance* and its mechanisms of sustainable quality assurance. As already mentioned, the model of the Max Planck Society was adopted in the establishment of the *Institute for Basic Research*, Korea. Similarly, Mexico and Columbia are also taking direction from this model at present in the development of their research systems.

Compared with the establishment of only elements of a campus university, the development of a top research institution the size of an individual Max Planck institute can be achieved with an acceptable level of expenditure. For this reason, some countries would like to have a Max Planck institute located within their borders. The Max Planck Society was pleased to accept the corresponding invitations of the relevant governments for its Florida and Luxembourg locations and is now represented by its own research institutes in these very different but scientifically very interesting locations. The decisive criterion for the involvement of the Max Planck Society or one of its institutes in such projects is the scientific gain that may be expected from the venture. The form and structure of the cooperation – not just with partners abroad – are always aimed at the optimum fulfilment of the Society's scientific objectives. As will be demonstrated below, the MPG has also developed a set of flexible tools for the institutionalised, temporally limited cooperation of its institutes with international partners.

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[74] The Sections of the Max Planck Society have set up Perspectives Commissions for the critical evaluation of their own fields and associated disciplines. Within these Commissions, they scrutinise their Section's research portfolio and design concepts for the future of individual institutes or new departments. The Commissions form an important element of the extension of the MPG's research horizon as a whole.

[75] Hollingsworth, J. Rogers. *Major Discoveries, Creativity, and the Dynamics of Science*, 2011. P. 118f.

[76] Hesse, Joachim Jens, *Die Internationalisierung der Wissenschaftspolitik: Nationale Wissenschaftssysteme im Vergleich.* Berlin: Duncker & Humblot, 2011. P. 417.

The fact that the Max Planck Society is sought after throughout the world as a scientific partner is proof of its scientific performance capacity. International visibility and networking are also a precondition of this performance capacity. Hence, strategic internationalisation is not a '*special case*' for the Max Planck Society, but a necessary condition for the fulfilment of its mission.

It can only fulfil its mission if it succeeds in appointing the best and most creative basic researchers in future-oriented research fields. It recruits these scientists irrespective of nationality from the most renowned scientific locations throughout the world. This is reflected in the MPG's personnel structure, in which foreign employees constitute over one-third of the work force on all career levels. For example, well in excess of 40 percent of the Scientific Members appointed at tenured W3 professorial level were appointed from abroad, and almost 90 percent of post-docs employed by the Society are foreign passport-holders.

At the same time, the MPG's scientists rely on cooperation with the top colleagues in their fields, irrespective of their location, so that they can participate in the very latest scientific topics and developments, advance the work on these topics, interact with each other and benefit from their mutual expertise in joint projects. Large research infrastructure, for example in astronomy and physics, can often only be jointly developed in the context of international consortiums.

When it comes to guaranteeing its scientific excellence, therefore, competition and cooperation on an international scale have been and are the central points of reference of the Max Planck Society.[77] Because they have intensified the dynamics of the innovation process and altered the constitutive conditions of nationally-funded research, globalisation and Europeanisation have further increased the importance and complexity of the international reference standard.

The Max Planck Society has reacted to these altered conditions with a comprehensive internationalisation strategy. As a counterpart to its institutes' *bottom-up* foreign cooperations, the Society has established a strategic framework. This includes centrally-managed international cooperation measures which are implemented in both the medium-term scientific interests of the institutes and in the long-term spirit of the research-policy orientation of the Max Planck Society as a whole.[78]

[77] Max-Planck-Gesellschaft, "Internationalität der Forschung - Internationality of Research. Symposium der Max-Planck-Gesellschaft", Max-Planck-Gesellschaft, 1997.

[78] Ebersold, Bernd, "Internationalität von Wissenschaft und Forschung. Selbstverständlichkeiten, Herausforderungen und Chancen internationaler Wissenschaftsbeziehungen im Zeichen der Globalisierung", in: *Sicherheit und Freiheit: aussenpolitische, innenpolitische und ideengeschichtliche Perspektiven; Festschrift für Wilfried von Bredow*, herausgegeben von Wilfried von Bredow und Thomas Jäger, 206–223. Baden-Baden: Nomos, 2004.

4.4 Selected internationalisation tools

The Max Planck Society's strategic internationalisation framework encompasses two complementary pillars, the first of which constitutes the attraction and integration of outstanding foreign scientists into the Max Planck Society. As already mentioned, due to its internationally visible performance capacity, the Max Planck Society is attractive as an employer to scientists of all nationalities and on all career levels. This excellence-driven *internationalisation at home* is an integral component of the Max Planck Society's mission to recruit only the best researchers as Scientific Members to its ranks.

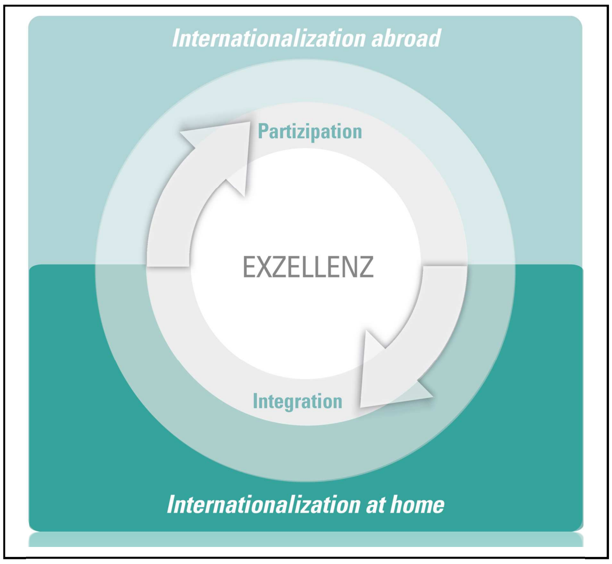

Figure 3: Strategic internationalisation. Source: Author's own diagram.

With the increasing globalisation of science, *internationalisation at home* is more reliant on supplementation through targeted *internationalisation abroad*. As the second pillar of internationalisation, this serves the strategic development of structural bridges to other countries. The purpose of this networking is the participation in scientifically excellent structures abroad as the precondition for the guaranteeing of an organisation's own performance capacity at an internationally competitive level.

The Max Planck institutes are globally renowned within their relevant *scientific communities*. In addition, the Max Planck Society deliberately attempts to make itself known to the youngest cohort of junior scientists, for example graduates from demographically-advantaged newly industrialised countries. With the *Science Tunnel*, *Science Express* and Images of Science exhibitions, it also attempts to generate awareness of it as a potential employer among this target group. Given that, due to its non-university status, the Max Planck Society does not feature in any of the international university rankings consulted by graduates from Asia and South America, it must increase its level of familiarity among potential junior scientists at international level through research marketing. This group is also increasingly being reached through *social media*. Unlike those of the German universities, the *followers* and *friends* of the Max Planck Society mainly come from abroad: only 20 percent are from Germany, with the rest coming from all over the world led by the USA.

The high level of familiarity of the Max Planck Society in the *scientific community* at international level, the global networking of its Scientific Members and the Society's international research marketing all contribute to the success of the MPG's most reliable internationalisation tool: the *International Max Planck Research Schools* (IMPRS), which attract the best junior scientists from all over the world to Germany. Of the approximately three thousand doctoral students attending an IMPRS, half originate from abroad. The fact that the system and structure of this graduate school are internationally renowned is a key factor in this success. Another reason for the attraction of the IMPRS is the fact that, as is the case in Anglo-American-style science systems, graduates with a Bachelor's degree have the possibility of being accepted into a *fast-track* programme in the majority of the schools. Beyond internationalisation, through the equal cooperation with the universities, the IMPRS also contribute to the linking of non-university research with the universities.

Moreover, several IMPRS maintain active partnerships with prestigious foreign universities, for example in France, Great Britain, Italy, Japan, the USA, Israel, Canada, the Netherlands, Austria, Poland, Sweden, Switzerland, the Czech Republic and Estonia, among others. This further increases the level of international network formation.

The additional formation networks by the IMPRS with renowned partners abroad shows that, in addition to traditional project cooperation, the strategic development of structural bridges with other countries is gaining in significance. This *internationalisation abroad* is given targeted support by partner groups abroad, the foreign institutes and the International Max Planck Centers. All of these tools combine the advantages of a longer-term planning horizon with the flexibility and high evaluation standards, for which the Max Planck Society is renowned. Unlike more short-term research projects, the structural institutionalisation of international cooperation at local level, which involves different levels, is paramount here. The increasing globalisation of cutting-edge research renders the maintenance of a presence in dynamically developing research locations increasingly necessary so as to facilitate participation in scientific excellence abroad.[79] This participation guarantees the scientific performance capacity of the Max Planck Society at an internationally competitive level and also generates synergies in Germany as a research location through the access it provides to knowledge and knowledge holders.

[79] "The fact that […] research institutes from Germany would like to and should have a targeted presence in an institutionalized form in research 'hotspots' has as much to do with the development logic of research as it does with the need to unfold the inherent international development potential for science in Germany with the research regions as a potential future 'hotspot'." Cf. Husung, Hans-Gerhard. "Zukunftsraum Wissenschaft: Was kommt nach der Exzellenzinitiative?" Wissenschaftspolitik im Dialog 6.2013 (2013). http://edoc.bbaw.de/volltexte/2013/2386/. P. 33

The international partner groups also illustrate this potential for synergy. In this case, the Max Planck Society provides support for its best foreign junior scientists who wish to return to their home countries in establishing a partner group located there, and in this way successfully contribute to the sustainable networking of the Max Planck institutes with top foreign junior scientists. This applies in particular to countries whose research structures are developing dynamically. Most of the partner groups are currently located in the promising research markets of China and India. These groups function through their connection with the Max Planck institutes as ideal points of contact with outstanding scientists from these countries, who wish to carry out research in Germany. This kind of access enables the timely attraction of strong potential partners for cooperation with Germany as a science location.

To establish lasting cooperation with strong local research partners, the Max Planck Society operates its own research institutes abroad in a few selected locations. As the experience with our foreign institutes has shown to date, this kind of ‘institutionalised bridge-building’ by the Max Planck Society is highly successful because of the Society’s decentrally-oriented structure with its flexible, medium-sized research institutes. Exactly like those located domestically in Germany, the institutes abroad are integrated into the MPG’s scientific Sections, the heart of its scientific self-organisation and, in this way, extend the Society’s international basis. It was thus possible to attract outstanding researchers for the Max Planck Society’s scientific community at the *Max Planck Florida Institute for Neuroscience*, who probably would not have moved to Germany.

At the same time, through the Max Planck Society’s institute in Florida, the excellence of German science is also becoming more visible in the cutting-edge research country USA. Together with the *Scripps Research Institute*, one of the globally leading American research institutes in the area of biomedicine, the MPG’s institute in Florida forms the cornerstone of one of the world’s most efficient neuroscience research clusters that is set to have a far-reaching impact.

Finally, the *International Max Planck Centers* provide probably the most flexible instrument for the structural institutionalisation of cooperation between institutes of the Max Planck Society and first-class partners abroad. The establishment of a *Center* is motivated by a shared interest in pooling complementary expertise in an innovative research area and in cooperating on a more sustainable basis than is possible through individual research projects.

What is special about this cooperation concept is that it unites both pillars of the strategic internationalisation: when one or more Max Planck institutes join forces with a top foreign research institution in an *International Max Planck Center*, scientists from the Max Planck Society benefit from the cooperation and the use of special infrastructure, as well as from the exchange of knowledge and technologies in other excellent scientific locations which include at present, for example, the *EPFL*, *Sciences Po* and *Princeton University*. The Max Planck Society also has *International Max Planck Centers* in scientifically-emerging newly industrialised countries like India.

The variety of possibilities available for the individual organisation of a *Center* is a key factor in the success of this tool: hence, a *Center* can be designed by the partners or junior research groups, an IMPRS or Max Planck Fellows entirely on the basis of the needs of the research field and the regional conditions. The exchange of scientists on all levels is a central element of all such *Centers*. Joint doctoral education and the promotion of junior scientists have been among the most common motivations for the development of a *Max Planck Center* to date. In individual cases, extra-institutional *tenure track* models have even been adopted in connection with the promotion of junior scientists. In general, the attractiveness for top scientists with all levels of experience and international visibility are significantly increased for both institutions involved in a *Center*.

Such activities attract excellent foreign scientists to Germany, in the junior scientist sector in particular. Thanks to the *Indo-German Max Planck Center for Computer Science*, the number of junior Indian scientists at both the participating Max Planck Institute for Computer Science and the Max Planck Institute for Software Systems has increased significantly. At student level too, a Center can contribute to arousing interest in Germany as a science location: for example, the Center established with the *University of British Columbia* has resulted in a ten-fold increase in the presence of Canadian students at the participating institutes.

The above-presented examples show that presence abroad also supports *internationalisation at home*. In this way, the combined effect of the two pillars of strategic internationalisation generates synergies that are essential for the Max Planck Society in the fulfilment of its mission and, at the same time, connect the German science system with the international research landscape. In view of the current demographic development in Germany and the dynamically developing knowledge society, this connection is essential for the long-term success of the German science system.

5. Outlook: The Future of German Science in the Context of Global Competition

Science policy - perhaps more than any other policy field involving the public service provision - faces the challenge of organising the opportunities presented by globalisation and exploiting them for the German innovation system. In modern high-tech countries like Germany and the USA, the abstract commodity ‘knowledge’ has long become a key raw material and the most important means of conserving societal well-being. National innovation and value-added chains build necessarily on this valuable resource. However, just as economic cycles can no longer be conceived of in national terms, today, the production of knowledge is no longer limited to a few science nations.

Globalisation has also enveloped the fields of science and research. Cutting-edge research is carried out in locations throughout the world that are characterised by ever-increasing dynamism. Countries like China, Korea and Singapore, which traditionally exported their best students to destinations like the USA and Europe, are investing massively in science and research. In attempting to establish attractive innovation locations, they are competing for the best students and scientists and for the investments of international technology companies. As demonstrated not only by the example of Korea, the targeted development of basic research capacities plays a crucial role in this process.

Basic research alone yields truly ‘new’ knowledge, and thus forms the basis for successful innovative milieus. And although this knowledge is increasingly available independent of locations, thanks to the revolution in information and communications technologies, the direct proximity of science and business is nonetheless an important condition for successful innovation regions: the dissemination of knowledge and interaction between research institutes, companies and universities is structurally bundled there in regional clusters.

Alongside the established research locations in the USA or Great Britain, these regional clusters are developing into increasingly dynamic innovation regions in Asia, India and South America.

For the future of the German science system, this means that our top national locations must not measure themselves by the yardstick of German performance alone. In the competition for the best minds, a high profile location in the area of biotechnology like Munich, for example, is already dependent on its research institutions and universities today to maintain the link with the top international science league.

This requires political support. Germany, like Europe, only has a chance of success in the international competition if it focuses on innovation. For a considerable time now, it has no longer been possible for the export nation of Germany to maintain its prosperity through low wages and access to inexpensive raw materials. For this reason, Germany must remain an attractive location for well-educated people, companies that engage intensively in research and, therefore, outstanding research institutions. Hence, policy should adhere to the objective of creating globally visible pinnacles in research and reinforcing existing strengths to become even more attractive at international level. The mere maintenance of the *status quo* means taking a step backwards in the international competition. The internationalisation of German research is not therefore an end in itself or an option, but a national task.

This task requires more than financial commitment. To fulfil it, reliable long-term political framework conditions are also required for both the universities and non-university research institutions. The associated social conditions are, perhaps, even more important: Germany has long been a country of immigration, not only in the field of science. This awareness must also be expressed – in all areas, not only science – in a spirit of social openness and culture of welcome.

Legende Grafik Seite 16

Konzentration der besten Köpfe = Concentration of the best minds
Studenten Wissenschaftler Internationalisierung = Students Scientists Internationalisation
Absolventen = Graduates
Forschungsergebnisse = Research results
Kompetitive Finanzen = Competitive finance
Öffentliche Finanzierung = Public finance
Stiftungserlöse = Foundation revenue
Studiengebühren = Tuition fees
Drittmittel = Third-party funding
Wissenstransfer = Knowledge Transfer
Förderlicher regulativer Rahmen = Promotional regulatory framework
Autonomie = Autonomy
Exzellenzkultur = Culture of excellence
Strategisches Profil = Strategic profile
Förderliche Governance = Promotional governance

Legende Grafik Seite 28

Internationali**s**ation abroad
Parti**c**ipation
EXCELLENCE
Internationali**s**ation at home