Science Institutions and Grand Challenges of Society: A Scenario[1)]

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1. Another Grand Challenge

Science and technology can, and should, play a role in meeting "grand challenges" of society. But how, exactly?

One can dream, and reason back from the "dream" (the vision of a desired state of affairs) to stipulate ways to realize it. Alternatively, one can diagnose ongoing developments, project what might happen, and attempt to modulate the developments to do better, somehow. In practice, both happen all the time, in the small, when strategic decisions are made, and in the large, as when nation states or consortiums of nation states like the European Union, draw up visions of the future (for example, Korea's *Science and Technology Vision for the Future* (KISTEP etc 2010), the *Europe 2020* policy document (European Commission 2010)) and may refer to them when deciding on actions here and now.

How do science and technology come in? One sees reference to "grand challenges" of society in science policy documents and background studies. Foresight studies create a perspective, and this can mobilize people and institutions. There appear to be two main ways to link science and technology to grand challenges of society. For example, when Research Councils UK formulated main priorities, one type could be characterized as 'responsiveness to national needs', the other type as 'exploiting technoscientific opportunities'. The two types lead to different styles of implementation and ways of mobilizing institutions. This is clear already in the brief descriptions of the priorities (RCUK 2009).

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1) This paper is the slightly revised version of my keynote address to the 3rd KISTEP Foresight Symposium, Challenges and Strategies of the Future, Seoul, 19 August 2010. I am grateful for the various comments I received, and for the help of Byoung Soo Kim (KISTEP) in preparing my keynote address.

Ageing: life-long health and wellbeing
There is an unprecedented demographic change underway in the UK with the proportion of young people declining whilst that of older people is increasing. By 2051, 40 percent of the population will be over 50 and one in four over 65. There are considerable benefits to the UK of having an active and healthy older population with potential economic, social, and health gains associated with healthy ageing and reducing dependency in later life. Ageing research is a long standing priority area for the Research Councils. The Research Councils will develop a new interdisciplinary initiative (£486M, investment over the CSR period involving all seven Research Councils) which will provide substantial longer term funding for new interdisciplinary centres targeting themes of healthy ageing and factors over the whole life course that may be major determinants of health and well being in later life. Centres will be focused on specific research themes drawing on the interdisciplinary strengths of the Research Councils, such as Quality of Life, Physical Frailty and Ageing Brain.

NanoScience through Engineering to Application
Nanotechnologies can revolutionise society. They offer the potential of disruptive step changes in electronic materials, optics, computing, and in the application of physical and chemical understanding (in combination with biology) to generate novel and innovative self-assembled systems. The field is maturing rapidly, with a trend towards ever more complex, integrated nanosystems and structures. It is estimated that by 2015 products incorporating nanotechnology will contribute US$1 trillion to the global economy, and that the UK has a 10 percent share of the current market. To focus the UK research effort we will work through a series of Grand Challenges. These will be developed in conjunction with researchers and users in areas of societal importance such as energy, environmental remediation, the digital economy, and healthcare. An interdisciplinary, stage-gate approach spanning basic research through to application will be used. This will include studies on risk governance, economics, and social implications

One can stipulate what science institutions should do, and in this example from Research Councils UK, there is a quite direct link between priority setting and institutional arrangements. Even then, it is often not easy to realize the priorities because their implementation is refracted through the interests and own dynamics of the various research performing entities. When the priority is formulated as 'exploiting technoscientific opportunities', its implementation is easier (because it gives free rein to the promises that scientists come up with) than when 'responsiveness to national needs' is put upfront. Sometimes, the two seem to merge, as when investment in nanoscience & technology is presented as furthering global competitiveness of the nation. The underlying assumption of eventual economic performance of nanotechnology is still quite uncertain, however.

In a first step, I propose to shift the perspective from priorities (in relation to grand challenges of society) and their implementation, to the question what existing and future science and scientific institutions can actually achieve. They cannot just be "commanded" to achieve whatever goals are set higher-up (not even in Korea where there is this strong sense that everybody should work towards further development of the country). Apart from the fact that research results cannot be simply produced as desired (some things happen to be difficult or impossible), there are interests and own dynamics of these institutions, embedded in structures and processes in (national) systems of research and innovation. What can be achieved depends on these structures and processes, just as much as it depends on foresight and priority setting. (There is more to say, of course, about inertia of existing institutions, about industry structures and national specialization, and about political and institutional cultures in a country.)

Thus, there is another Grand Challenge: how to grow, maintain and keep productive a research and innovation system (national or otherwise). The Korean *Vision for the Future* (KISTEP etc 2010) discusses this in Part V, but does not offer much background analysis. This is a general phenomenon: concern about the research and innovation system and its productivity (along a number of dimensions) is quickly rephrased comparatively, and in terms of competition: are we doing as well as the Americans, or the Japanese? And the concern is further reduced to comparisons of indicators, rather than substantial diagnosis of structures and patterns and institutions in the system which shape what is no, produced, and may be produced in the future.

In general, while the challenge of institutional capacity building (including receptivity to grand challenges of society) is recognized, actual measures tend to be ad-hoc and superficial. Hobbyhorses of key people and dominant narratives (like the linear model of investing in science and technology to realize innovation to realize economic growth) continue to be more important in shaping what happens than in-depth analysis and diagnosis of what is happening and what future developments of the system could be. For the record, I add that existing scholarly literature and reports on national research and innovation systems often suffer from the same limitations (and tend to be very descriptive). More sophisticated approaches are being developed, however, particularly in Europe (see for example Smits and Kuhlmann 2004, and Schön et al. 2010).

In a second step, I will discuss the Grand Challenge of science institutions and national systems with the help of a foresight exercise. I will create a scenario about their further development which is informed by the more sophisticated approaches to science institutions (see Rip 2000, Rip 2011, and for the scenario approach in terms of 'endogenous futures' also Robinson 2009).

The scenario should be seen as a thought experiment, in which one can explore what might happen. In the thought experiment I present, part of my focus will be on trends that have perverse effects. Not because I want to paint a doom scenario, but to show how one can learn from a scenario exercise about ways to do better.[2)]

2. A Scenario about Changes (up to partial collapse and revival) in Science Institutions

I will present the scenario in three stages: the present, the near future, and the "cusp" of 2018 and its aftermath.

2.1 The Present: It is the year2011, and the landscape of science institutions worldwide is under a variety of incentives and pressures.

Research universities write mission statements that emphasize excellence in research as well as their ability to serve society by contributing to innovation. They announce their intention to be in the top 100 of the Shanghai ranking, as the University of Göttingen in Germany did when submitting its bid to the German Federal Government's Excellenz Initiative, and the University of the Witwatersrand in South Africa did to show it wanted to recoup its status as an excellent research university. In Korea's *Vision for the Future*, it is stated that there should be 10, rather than the present 2 universities among the top 100 universities. – The Shanghai list will become crowded …

This trend is pushed by governments and government agencies asking for indicators of performance, up to cultivating Nobel Prize winners (as the Korean *Vision for the Future* phrased it). Scientists and science institutions respond by working to meet these indicators, somewhat independently of their actual, substantial performance.

At the same time, the promise of high technosciences like genomics, stemcells, nanotechnology, now also hydrogen economy, is pushed by (some) scientists and (most) government agencies alike. There are attempts to identify "key technologies" that a country (examples can be given of France and Germany) can invest in, in order to "pick winners". Somehow, every country

2) In this respect, my scenario has the same function as the system-dynamics-based 1973 Report to the Club of Rome, which focused on limited global resources and environmental degradation, and created an early warning message. Korea's *Vision for the Future*, in its emphasis on green technology, takes up the message in a pro-active way. The focus on 'green technologies' is an attempt to mobilize science and technology to avoid the doom scenario – and create a globally competitive advantage for Korean industry at the same time. My scenario might help to identify further locally productive and globally competitive approaches.

seems to go for the same "winners", at least in high technosciences.

A key part of these dynamics are funding races, very visibly so for nanotechnology (Figure 1). In spite of governments' interest in innovation, it is a funding race and not an innovation race. Firms tend to be reluctant to invest heavily in nanotechnology, because of uncertainties about eventual performance, as well as concerns about risks and about public acceptance. Consulting company Lux Research has now moved to focus on green nanotechnology as the way forward.

This is not the whole story, however.

Research universities can include community orientation in their "third mission", and do so (and have to do so) in Latin America and Southern Africa. The lure of excellence remains strong, however.

At the side of innovation, there are pockets of user-driven and community-based innovation (compare Von Hippel 2004), the open-source movement, farmers' collectives etc where global competition is less important (see the analysis in Joly et al. 2010, who call this type of innovation 'collective experimentation').

There is a third development, where scientific knowledge production is opening up to accept input from other parties than professional scientists. Such inputs can come from stakeholders wanting to influence directions of research, or they can be invited by science funding agencies and other bodies to offer their views. The input can also be into knowledge production itself, as in health (contributions from patient associations), environment (consultancies and NGOs) and agriculture (farmers' collectives). Experience-based knowledge can then be integrated with professional-scientific knowledge production. As a trend, this overlaps with 'collective experimentation' as a mode of innovation.

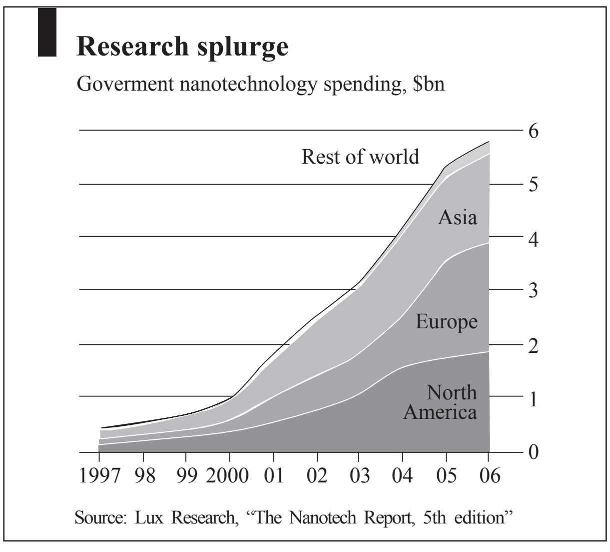

Figure 1 Research splurge

These recent developments are still on the margins of the dominant narrative about excellence and the promises of high technosciences, however. Another opening up that is not at the margins anymore, is the question of scientific (or research) integrity. Even if fraud and plagiarism etc are often treated as a matter of individual failure rather than a problem of the system, there are system-level initiatives. The USA continues to have an Office of Research Integrity, the European Science Foundation has a working party on scientific integrity, and there are proposals for Codes of Conduct by established science institutions like Academies of Science.

A further step in this direction is that epistemological debate about research findings, methodologies and background perspectives is not limited to professional scientists anymore. Committees of the USA Congress are willing to expound on what is "sound science" – which for them excludes theoretical speculation and modeling (as in climate change research) in favour of empirical research, i.e. collecting "hard" data. From a different starting point, but with the same thrust (scientists need not have a monopoly on what is good science), indigenous and community knowledge and perspectives are pushed as real alternatives – and sometimes taken up as such, as in a New Zealand government Maori-oriented research funding program (Rip 2002).

The variegated developments I sketched here all attempt to open up scientific institutions to broader considerations and broader inputs. In Figure 2, I position them as a next step in recontextualizing modern science (since the late 19^{th} century – since 1870, to be precise). Earlier recontextualizations led to new public research institutes and subsequently, strategic research (funding) programs, and Centres for Excellence and Relevance.

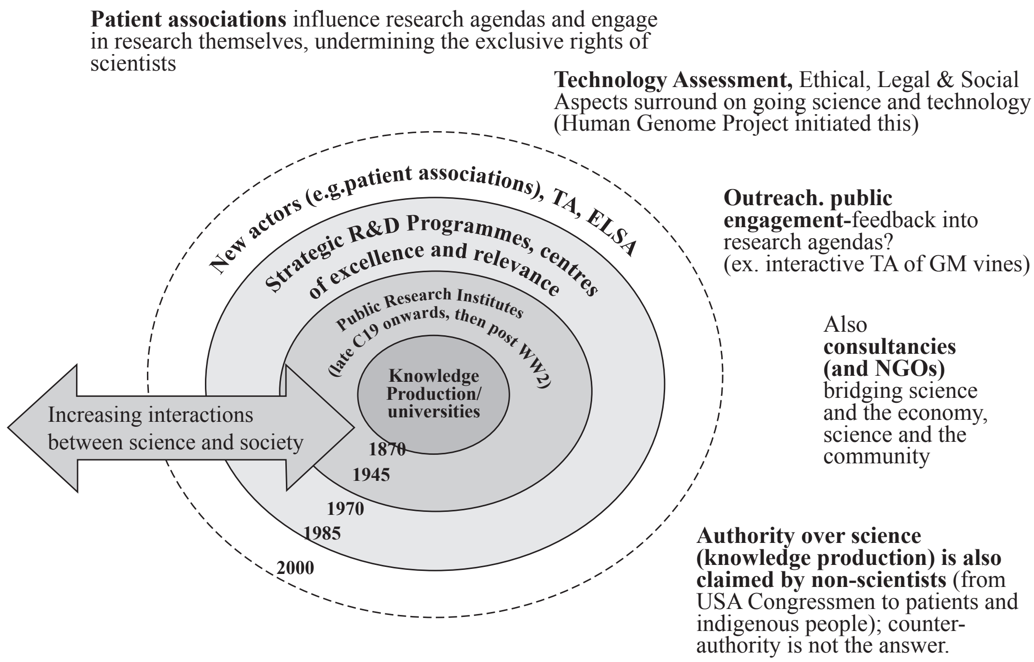

Figure 2 Increasing re-contextualization of science in society

2.2 The Near Future: Given this evolving situation, with scientific institutions pursuing their own and often short-term interests, and responses from various societal actors and audiences, what might happen in the next 3 to 6 years?

Three main dynamics were outlined for the present: excellent research, science for innovation (mainly high technoscience), and opening up to new stakeholders. The further dynamics will be influenced by contexts and circumstances, of course, but I will abstract from such contingencies for this scenario exercise. And contingencies, even if major in their own right, may not have a large impact on the evolution of science institutions. For example, the present financial and economic crisis will have effects on spending on science and technology, but there is also a strong feeling that investments in science and technology will help overcome the crisis, at least in a long term perspective. More important are circumstances that are incited by the present dynamics, for example disappointments about what science and technology actually deliver, and thus a tendency to be more realistic about the promises of new science and technology.

The present patchwork has three strands that are important for the scenario: (1) the focus on indicators, which gives rise to a "derivatives" industry; (2) the attempts to link high technoscience with actual innovation and uptake; (3) some de-professionalization of science.

The first strand is dramatically visible in how the Shanghai ratings for universities have become a "derivative", foregrounding indicators rather than substantial excellence. A trade in means to achieve high scores on the indicators has emerged. As on the stock exchange, there is strategic buying and selling (of top researchers, of creating centers of excellence (and relevance), of setting priorities that follow the fashion). All this while basic research funding decreases, and universities have fewer margins. The League of European Research Universities warns against such a reputation race (Boulton 2010), but finds itself helpless against it, also because its members continue to refer to the ratings (especially if they are favourable) in public statements.

More and more aspiring research universities want to make it to the ranking. Thus, a demand emerges for ways to score. Since ratings (Shanghai and others) take awards and prizes into account, there is an interest in getting such prizes, but also to have more such prizes awarded. Actually, there is a supply:

various bodies and rich individuals (the Kavli Prize is an example) start giving awards for excellence. In such a situation the tongue-in-cheek proposal on a blog of a scientist to have the Nobel Prize Committee award more prizes (there's much more research done now compared with fifty or one hundred years ago, so also more occasions to recognize and reward excellence) becomes a topic of real debate, up to pressures exerted on the Nobel Prize Committee to do something about the proposal.

The other race continues as well. Even if the focus of the promises might change, e.g. from nanotechnology to synthetic biology (as happens in the US), the pattern remains the same. Investments are argued in terms of global competition, and phrased as a race: we have to be first! Scientists go along: "high tech means high funding", whether it is actually useful or not. While there is increasing recognition that the promises are not easy to realize, the promise race continues. Like the arms race, it has a dynamic of its own. Even with the financial crisis, high technosciences continue to get funding, because it holds out hope of recovery.[3)]

At the same time, there is increasing reluctance to buy into the promises as such. Business firms which have to deliver a product in the end had been reluctant all along (up to the point of being myopic, at least prone to waiting games, cf. Parandian et al. 2010). A pro-active approach emerges, somewhat independent of the overall promise race. The gap between techno-scientific promises and actual products/ services can be bridged by 'translational research'. The notion was used in drug development to bridge gap between proof of principle (of the working of a drug) and the actual formulation and administering of a drug in practice, and is now generalized to be a necessary complement to all promising techno-scientific options. New sponsors like the Bill & Melissa Gates Foundation start to emphasize translational research (without necessarily using the term) in addition to pursuing promises.

Thus, the 'market' for strategic research (Rip 2004) evolves further, now including translational research. Public research institutes, company R&D units, and some university departments become regular suppliers. It is not a classical market with independent suppliers and customers. The European Technology Platforms, pursuing anticipatory strategic coordination between research, uptake and projected use, become increasingly important as intermediaries, and in other regions of the world there are attempts to follow their example, or graft it on own ways of anticipatory coordination (as in Japan and South-Korea).

Two further, and in a sense complementary, movements occured with respect to the promise dynamics. Funding agencies in Europe started to require extended impact assessment (this is European Union terminology; the US National Science Foundation speaks of 'broader impacts criterion') as part of research proposals. At first, it remained limited to a few additional paragraphs in research proposals. But the logic of competition (for funding) kicked in, and proposal writers knowing their score could be increased by having a good impact statement started to hire consultants to write up such statements. The work of the experts assessing the proposals became more difficult. After a few years of learning by trial and error, the situation stabilized, and included links to translational research.

The fact that promising new science and technology also led to concerns, up to resistance (as with green biotechnology) had been a reason to include ELSA (research on Ethical, Social and Legal Aspects of the new science/technology) in funding programs, already in the 1990s for genomics (Rip 2009). This also happened with nanotechnology, but was now placed in the broader framework of 'responsible innovation' (or 'responsible development'). The reference to 'responsible' creates openings for more stakeholders, and for civil society generally, to be involved (Rip 2010). This remained tentative, however, even while there were interesting examples in some countries that might be taken up elsewhere.

3) There is some sense in that: counter-cyclical investing. But this requires courage, and a feeling for what is, or may be, important. When decisions are predicated on a competition logic, however: doing better than others, and thus create wealth, somehow, they may be self-defeating, because everybody converges on the same priorities.

The opening up that is occurring is still predicated on high technosciences, which had been a world onto itself and is now being contextualized. If one does not start from this world, a different picture emerges. There is collective experimentation (Joly et al. 2010) going on, which can take up high technoscience, but on terms set by the collective experimenters. High tech innovation in professional and amateur sports is a good example, but also "technoblending" in developing countries, when local technologies and experiences are combined with imported technology in a productive way.

A different picture also emerges in the health sector. The constructive role of patient associations continued. This was reinforced by a reconsideration of the high-science approach. As Berwick (2005) phrased it: The movement for evidence-based medicine (..) transcended and improved upon local, experience-based knowledge, but has now "overshot the mark" and "excludes too much of the knowledge and practice that can be harvested from experience". While the opening-up that is occurring in a variety of ways may signal de-professionalization, the question of quality control (and quality assurance) has to be addressed even if traditional professionalized science is not the only arbiter anymore. Actually, re-professionalization occurs, as in the integration of Chinese traditional medicine and so-called Western medicine, in China, and also in Australia.

Thus, the evolving patchwork has recognizable strands, but there is no overall integration. Maybe one should not ask for overall integration, just go for "muddling through" (as Charles Lindblom phrased it, cf. Lindblom and Woodhouse 1993). But the "muddling through" might be hampered by the distance between excellence and high technoscience promises on the one hand, and the ongoing activities in research, product development, and collective experimentation on the other hand.

2.3 The "Cusp" of 2018 and Its Aftermath

The patchwork of developments might have continued in its amorphous and stumbling ways, were it not for a triggering event and its repercussions.

Remember the pressures on the Nobel Prize Committee to do more? When the 2016 Nobel Prizes were awarded in November of that year, the Committee also announced it would start awarding Nobel Prizes every half year, rather than only once every year. Subsequently, others felt free to start awarding prizes, or increase the frequency of prizes they were awarding already. After the first enthusiasm from the side of researchers and science institutions, there was a realization that the proliferation of prizes reduced their exclusive value. The various rating lists of universities which, because of the dynamics of the reputation race, had continued despite the criticisms of their methodologies, now lost their legitimacy: researchers were not interested anymore, and government bodies and funding agencies stopped taking such indicators of excellence into account. By 2018, the reputation race lost its thrust – this bubble of "derivatives" had burst.

Research universities were at a loss what to do now. Also, the groundswell of other kinds of universities (higher education institutions) increasing in numbers and variety could now be recognized for what was happening and what it might imply. Dedicated niche universities and colleges (up to indigenous universities in Latin America, and universities set up by millionaires in India) suddenly became visible as legitimate. Some of them followed the pattern of US community colleges, with no research, others were doing research, but often outside established research categories. Diversity was recognized as important.

One "bursted bubble" led to another. The dynamics of high technoscience promises, somewhat eroded already because of the interest in translational research, were now turned around: promises had to be accompanied by specifications how to achieve them. The license for doing excellent research now became: if no (attempt at) translational research, no support/funding for basic research.

Some institutions (new universities, public labs, strategic research programmes and centres of excellence and relevance) embraced this, because it justified their existence and thrust. Other institutions, in particular traditional research universities, accommodated so as to survive.

The shift towards realism when promising high technoscience made the original narrative less dominant, and thus allowed recognition of the value of other approaches (versions of collective experimentation). These had been important in practice already, but now became part of the official agenda.

All this worked out differently in different countries. Techno-scientific promises remained important in China and other Asian countries, although some, like South Korea, considered embedding in society as well. Globally, the net effect was that the importance of technoscientific promises in decision making about funding and about the role of research in meeting grand challenges became less, and there was more attention to what could actually be done in the short term.

There were protests about such short-termism. While many of these protests were just attempts to recover the freedom of scientists to go for excellence and for high technoscientific promises, the issue of short-termism remained important. Over time, the pendulum might swing back.

3. Conclusions

Different types of conclusions are in order.

One is about the starting point, how to meet grand challenges. The basic message is: they were not met at first, because excellence and promising games were dominant. When the bubbles had burst, more concrete linkages were up front, but still as a patchwork, with no assurance of results. Maybe the whole idea of grand challenges should be seen as a mobiliser, enabling further work, rather than something that can and should be achieved.

Another conclusion is about science institutions. There is inertia of institutions (universities, funding agencies, government ministries). And there are the self-inflicted constraints of participating in reputation and promise races. Even when such patterns are recognized for what they are, institutions cannot easily step out of them. Only when the perverse effects of such patterns come home, they are able to take action.

At the system level, the important point is about diversity. Many well-intended policies may reduce diversity, and thus incentives for creativity and productivity. Reputation and promise races also push convergence rather than diversity. There are counter-currents (collective experimentation, non-professional knowledge production), but they will not come into their own unless the bubbles burst. Perhaps (and ironically) one should push the bubble so as to make it burst earlier, before it creates too much damage.

This then has implications for foresight, and in two ways: the methodology of foresight, and the role of foresighters.

Foresight has to take non-linearity of developments into account, where actions and reactions determine what happens, rather than some overall trend (cf. Robinson 2009). The collapse of the dynamics of ranking (as a derivative) is an interesting possible future. It is a thought experiment and need not happen that way. But it has a certain plausibility to it: things might develop this way in our kind of world.

One need not agree to the specifics of the scenario I presented here, but the methodological message is still important: there can be, and will be, non-linear developments. Which require scenario exercises rather than trends and roadmapping.

Foresighters are not just desk researchers who write a report. They are part (even if only a small part) of the dynamics they attempt to describe and diagnose. My own work on the future of research funding agencies is a case in point (Rip 2000), because it developed from interactions with funding agencies, and funding agency staff (in various countries) continue to invite me as a commentator. Foresight exercises like the Korean Vision for 2040 are more distant from present practices. But also there, one can envisage interaction with various actors who are making choices and decisions.

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