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Quality without Quantity[†]

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For knowledge itself is power
Francis Bacon

Introduction

Supporting the ongoing quest for new knowledge is a challenge for all countries, large or small. The foundation for this quest is a vibrant research base, which is the primary tool to create and maintain a knowledge-based society. A knowledge-based society encompasses knowledge (facts, truths, principles), processes for gaining knowledge (e.g. through systematic studies and research across all fields of endeavour), and mechanisms for recording, disseminating and preserving this knowledge. A hallmark of a successful knowledge-based society is the generation of high quality research. This poses a serious challenge to small countries – how to achieve quality with limited resources – in other words, how to ensure quality in research, without being quantitatively rich in human or material resources. This essay draws from the deliberations and discussions of the ALLEA Working Group *National Strategies of Research in Smaller European Countries* (ALLEA, 2002), but the views expressed are those of the author.

Reflections on systems

The focus of the comments to follow is on research, research structures, and policy. To begin, though, I will take a broad look at physical and mathematical structures and systems, as a way of providing useful models for thinking about research structures. Of course, natural sci-

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ence or engineering models cannot be used directly to describe more multidimensional and complex social systems. Nevertheless, such models may prove useful by analogy, inference or concrete representations.

An old idea is that structural strength is based on a strong foundation. The wider (and stronger) the foundation, the higher (and better) structure. Pyramids are one example of structures that have resisted more than 4000 years of changes. By analogy research systems in many large countries can be so described: the sheer size of a large research foundation is likely to produce remarkable results. But is a broad foundation the only factor for fostering quality research? A structure with internal organization may provide another model. For example, research structures could be organized as matrices. This means arranging the reasons and results into a system of rows and columns while every element shows a strength of interaction. Such a two-dimensional set-up could be generalized easily to higher dimensions (cf. physical crystals).

Matrices are regular structures and such a regularity is sometimes an advantage but sometimes a disadvantage. Regularity gives a possibility to have a clear overview on a system and consequently such a system is easier to manage. On the other hand, regularity introduces restrictions in expanding or changing the system that should follow strict rules. A step forward is to use instead of regular matrices the concept of fractals. Roughly speaking, fractals can be described as networks where links between the elements are irregular and every element, if enlarged, has an internal structure with more links which are not visible at first glance. Such a fractal network may be useful to explain interdisciplinary, interregional, international, and inter-society influences on the quality of research. Stronger elements (laboratory, centre, university), would lead to more and stronger links that could serve to transmit ideas, increase potentials, enhance internal structures, carry funding, and so on. Such a model could capture the dynamic character of a network: intensive outflux could destroy an element (a node), elements could be united, etc. Some elements could be attractors and therefore more visible. Another analogy from fractal structures is that complex structures are generated by simple rules. By repeating those rules, again and again, an initial simple structure may become complicated.

A fractal network may be a good model for growth in research structures, especially as research becomes more international. Indeed, one cannot think about working in solitude in the contemporary world at the risk of reinventing the bicycle. Ideally, science is complex, science is open, and there are no borders between researchers. Contemporary science, however, does not meet this ideal – there is no ideal language easily understood by others, not all science is conducted under the same work conditions, the links to society vary. But this model may be useful for describing quality in terms of its underlying structure – fractal network or web. The elements (nodes) in (and of) small countries can be as effective as those in larger ones, provided they are visible and attractive.

What is going on

There is an inherent tension between the goals of science and society: scientists would like the freedom to pursue research that is driven by science; society would like to get results. Yet, the effectiveness of science depends on a balanced interaction. Scientists have a dual obligation – to explore fields that are unknown, and to apply what is known in research directly for society's needs. Runciman (2002) has said: "A knowledge society, as it is nowadays called, must be a society in which scholars and scientists owe to the state the same obligations as any other citizen, but the state recognizes their right to pursue their vocation of 'Wissenschaft' without any restrictions beyond those imposed by best practice and the law of the land." However, again citing Runciman (2002): "...but discoveries can never be made to order and the outcomes of original research can never be predicted in advance", suggesting that the mechanisms for fulfilling this dual obligation may not be direct.

When discussing research structures in a country or region (Europe), several basic ideas are usually followed. These include:

- quality of research should be promoted;
- networking and mobility are important;
- governmental funds and/or incentives should be created for priorities;
- there should be mechanisms for disseminating knowledge to the public;
- research should follow strong ethical principles (cf. for example EC, 2000).

In addition the formulation of research policy faces further challenges (Kuklinski, 2000):

- promotion of equality of opportunities or resources versus efficiency in outcomes;
- support for individual freedom in research versus collective order;
- adoption of spiritual versus material values;
- reliance on short- versus long-term thinking and planning.

The situation is spiced with many constraints on the research enterprise in all countries, but these are especially acute in smaller countries. They include insufficient funding, limited human resources, structural weakness, etc. What strategies can be followed in such a complicated situation? The answer seems clear – the only way is to run as fast as possible. In other words, if a country realizes the importance of science and technology in fostering its future well-being, and formulates a clear and successive research strategy then those (or at least many of) difficulties could be removed. Two main goals of such strategies are: to enhance the welfare of a country and to enhance the pool of knowledge. The first goal speaks to the aims of government and the public, the second goal speaks to the aims of science.

A good example is Finland where the fruits of activities in the 1980's are visible now (Academy of Finland, 2000). A brief overview of Finnish activities is presented as a case study in the ALLEA Report (ALLEA, 2002). An important aspect of the Finnish approach is the understanding that although research is a pillar of society, the pillar itself always needs renovation and a fresh perspective. An important recent document is the international strategy of the main funding council in Finland – Academy of Finland (International Strategy, 2002). It states as objectives being an active and influential force in general European research policy, a respected global player, and an attractive partner for cooperation.

An example of a country that faces many constraints and challenges is my own country, Estonia. The constraints on this small country (1.4 million population) are clear (Engelbrecht, 2002):
- limited qualified manpower;
- limited funding;
- a need to keep the national universities functioning;
- a need to foster research to underscore national identity (language, history, nature, etc.);
- a need to foster basic research to guarantee quality in higher education and to allow talented people to work at home in these fields;
- a need to foster applied research and development to infuse innovative

ideas into industry.

Clearly the needs must be balanced. This is possible only by making choices. Incentives for quality in research have been introduced already, and include the following:

- peer-review is the basis for all funding decisions (both for top-down and bottom-up initiatives);
- international evaluation of research is a rule;
- support is provided to young people in research including a special fund for the PhD research, post-doc positions, special PhD and MSc research stipends from grants;
- private sources are attracted to improve infrastructure, PHARE (support to Central European countries) programmes have been used to support Competence Centres;
- national programmes for centres of excellence in research and research professorships have been launched.

In addition, the participation in the FP and ESF programmes, other EC schemes, and bilateral co-operation have shown that research in Estonia can be competitive. A policy initiative, The Research Strategy "Knowledge-Based Estonia" was approved by the Estonian Parliament in December 2001 (Knowledge-Based Estonia, 2002). In this strategy, the roles of the government are defined as an investor, a catalyst and a regulator. Key areas to be supported based on the existing scientific potential and possible applications are:

- technologies for an information society;
- biomedicine with applications;
- materials technology.

Activities to enhance the innovation structures are in progress.

Are these measures sufficient to ensure quality without quantity? While the EU has set targets for funding research of up to 3% of the GDP, Estonia still fights to pass the 1% margin! Nevertheless, the case studies from smaller European countries like Finland, Ireland, Portugal and Austria (see ALLEA, 2002) have shown that such a consistent science-driven road is the only way to the knowledge-based society.

A challenging question is how to measure quality. Scientometry gives some answers but is it enough? The first indicator is the well-known percentage of the GDP that a country allots to research and development. This is certainly an indicator that sound research can be based on a correspondingly sound infrastructure. There is an expectation that the 1% margin should be passed for a country to benefit from research and development. Again Finland is a good example, passing the 3% margin in 2000 (High Technology Finland, 2000). Many candidate countries to the EU in 2002 are however under the 1% margin. Does it mean that quality is lost? With a low margin, it would certainly not be possible to support accelerators or other large-scale facilities but these can normally be maintained by united international efforts in the contemporary world and smaller funding should be better allocated anyway. Another indicator is the number of peer-reviewed papers published in the country or in a region. Usually this indicator is based on CC[1] papers, followed by citation rankings. Much has been written on the correlations between these indicators and economic success. Leaving aside the discussions on that topic (cf. for example Pačes et al, 1997), let us consider some examples.

Matthiessen and Schwarz (2000) have analysed the SCI[2] data on publication records of research centres in Europe over 1994-1996. According to Estonian data, (Tiits & Kaarli, 2002), the Tallinn-Tartu region has about 2 papers per 1000 inhabitants over the same period and 3.2 papers over 1998-2000. This is the same level as of Hamburg and Budapest (Matthiessen & Schwarz, 2000). If, however, we take only Tartu, a university town with 100 000 inhabitants, then data over 1999-2001 show the level of 12 (TU Annual Report, 2002). This is the level of Stockholm-Uppsala, and Copenhagen-Lund (Matthiessen & Schwarz, 2000). Given the number of cited papers in Estonia per year (635 in 2001, see Tiits & Kaarli, 2002) and the number of inhabitants (1.4 million), the number of papers per 1000 citizens is 0.45, which is not very much different from the corresponding figures of leading nations (Rauch, 1999). All these figures should actually be weighed against the corresponding R&D funding which is much less in CEE countries compared with the EU or OECD average, not speaking about the best examples like Sweden and Finland. The corresponding data (EC Communication 2000; Tiits & Kaarli, 2002) show that the R&D funding is about 3 times less in percentage and in real value of GDP the difference is much larger. This suggests that the quality requirements are high also in small candidate countries and given the level of funding, the potential should be better used.

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[1] Current Contents

[2] Science Citation Index

Bullock (2002) has analysed the guiding criteria in funding policies to ensure quality. She also says: "...it is important not only to promote the production of excellent science and scientists, but also to put in place mechanisms to ensure integration into world science..." (cf. again the experience of Finland – International Strategy, 2002).

What could be done

First, some general observations. In the modern world, new knowledge is generated either by science driven research or by technology driven research or by issue driven research. There are different tools to support research in these areas. Roughly speaking, the first area should be supported by the governments to guarantee continuity in research and education (and also to give the possibility of unexpected results). The second area is mainly supported by the economy (industry). The third area is directly related to state or national interests like health, environment, etc. and research in this area is often supported by special programmes. Collaboration across all areas and actors is needed. A trilateral collaboration across industry, government and academia is nowadays called the triple helix model of innovation (Etzkowitz, 2000). The collaboration means also overlap in institutional spheres creating knowledge, consensus (among academic, public, and private sectors) and innovation spaces.

The idea of the European Research Area (EC Communication, 2000) fosters this conception. Many institutions, such as the European Science Foundation, CERN, EMBO, Academia Europea are developing programs to support collaboration among various actors. ALLEA has an important role to unite the voices from national academies fostering science and humanities.

Today the national structures of research in European countries and pan-European enterprises are combined to produce a complex system. Clear differences in capacity between Europe and the US provide a challenge to policy-makers. Funding of research in Europe is behind the corresponding level of partners. Within Europe, the EU has at its disposal just about 5% of the total resources for research funding (EC Communication, 2000). In FP objectives a mysterious 'European added value' is stressed. What is it actually? One could say that a good collaboration always has a synergetic effect. Does this automatically confer an added value? And researchers complain often about complicated rules applying for EU projects. We may even paraphrase a well-known saying from the 19^{th} century: “A spectre is haunting Europe – the spectre of bureaucracy.” Heretic as this may sound, the challenge of complying with EU bureaucracy is a real threat. From the origin of the saying, paraphrased above we know that then “all the powers of old Europe have entered into a holy alliance to exorcise this spectre”. Are we now also united?

The above lines are certainly not novel. The EC 'Science and Society Action Plan' (2001) is focused on how to promote a culture of science and education in Europe and how to bring science closer to society. However, the activities of the EC have also been strongly criticized (Monnet, 2001). Leaving aside the details, the keywords used to describe EU actions are certainly sound: openness, participation, accountability, effectiveness, and coherence (European Governance, 2001).

Let us focus now again on research in smaller countries. The European Research Area (EC Communication, 2000) has indicated several instruments for supporting research. These are: mobility, networking, centres of excellence in research. What is the impact for smaller countries with limited possibilities?

An analysis of research strategies for smaller countries has been presented in the recent ALLEA Report (2002), including a summary and several case studies on Austria, Czech Republic, Estonia, Finland, Ireland, Portugal, and Slovenia. In a process as complex as research management, there are many common activities and also several specific initiatives. Common activities include the need for science policy, and the importance of evaluation exercises. Calls for targeting of funding, co-operation in research, foresight programmes are stressed. Several specific incentives are introduced like funds for realization of government priorities and/or innovation, special tax incentives, S&T levy on certain industries, national programmes for Centres of excellence in research, national interests, and material infrastructure, incentives for young scientists, etc. (see ALLEA, 2002, and Section 3 of this essay).

Can all the ERA ideas easily be implemented? Are the FP areas and tools envisaged in the Action Plan of ERA equally possible for large and small, for members and candidate countries? The aims are clear (EC Communication, 2001): promote scientific and educational culture in Europe, bring science policies closer to citizens, put responsible science at the heart of policy making. These general ideas should be met by the initiatives of member (candidate) countries. But here, I am afraid to say, is where the main difficulties are nested, especially in smaller countries. This concerns not only national interests but also the equal chances for participating in European projects. ALLEA (2001) has clearly called for attention to smaller laboratories and research groups.

Let us quite openly put one issue on the table. Large countries and international agencies protect their markets. Rules have been worked out indicating quotas to sell the goods, emphasis is put on stock values, etc. The knowledge pool has neither a quota nor selective rules. Peer-reviewing is a tool and a filter to guarantee quality. Nevertheless, much depends on funding and the question is, are the rules of funding equally acceptable for all? One should never forget that competition exists almost in all human activities.

Certainly there are more questions than answers. Questions could also be raised about the science itself in very general terms. We expect new results from molecular biology and gene technology, from nano- and information technology, and we hope for breakthroughs in understanding human behaviour. Much funding goes to the disciplines that carry out that research. But sciences deal with the full spectrum of knowledge. What about the other disciplines, the so-called 'orchid subjects'[3], mostly in the humanities? The Swiss Academy for humanities and social sciences has recently raised this question (Colloque, 2002). These disciplines are even more important for small countries not only in relation to university teaching but to foster cultural integrity.

Leaving aside the difficulties, let us focus on concerted actions. Three keywords need to be clarified: mobility, co-operation, networks. What is actually mobility? Briefly, it refers to researchers visiting others laboratories for shorter or longer periods of time. In all the discussions around ERA two-way roads are stressed, meaning an exchange in both directions from one lab to another and vice-versa. In practice we know that it does not work that way – researchers try to work in CERN or in Cambridge or in some other centre wellknown internationally. Why? The reason is simple – mobility is towards action (Siotis, 2001). From that definition a condition for a two-way road follows – what is done should be visible. Only then is action seen and mobility as such works. Following this thread – visibility means excellence in research. That is also a precondition for networking because real co-operation

[3] Small and rare fields of research, still important in general context

needs equal partners, not the strong helping the weaker. In addition, education is more effective if combined with excellence in research. One could paraphrase a famous saying – if someone has been lucky and worked as a PhD student or a post-doc in a centre of excellence in research, this remains for life! May (2002) has used another aspect to emphasize excellence like "...institutional culture in which the best young people are free to express their creativity...".

Returning now to the idea of research structures as fractals (see Section 2) one might consider developing an elementary rule or an elementary brick to build up a larger network. There is a simple rule – support the quality. This can be done in centres of excellence in research. The main challenge to applying this rule in small countries is capacity. That leads to the conclusion – the most important element is to educate young people. Bearing quality in the mind, education is most effective if it occurs where the best research is carried out. This closes the elementary loop: quality and education combined. This elementary loop is able for networking and co-operation and will serve the community in the most effective way. Certainly it is not simple. For example, in smaller countries the needs of the community and excellence in research may not overlap in everything. This is one of the issues in CEE countries that can create a lot of tension. Nevertheless, the only way to overcome these difficulties is to apply the simple rule formulated above – support the quality. Or in other words (May, 2002): "...finite funds must be distributed selectively rather than by egalitarian formulae". Having said that, I want to stress a real challenge – not everybody understands quality. It is necessary to enhance the public understanding of science – a formidable challenge in our increasingly globalized world, especially in countries undergoing fast transition like CEE countries. Concentration on short-term targets and stressing cash-in-cash-out principles are some of the main features of misunderstandings and tension between science and society. In order to overcome such a gap, science needs to be popularised. Maugin (1992) gives at least five reasons why scientists themselves should be more active in communicating scientific knowledge to society, i.e. to non-scientists:

- science should be made understandable to governments and funding committees because the funds allocated to science must be explained to taxpayers;
- there is a natural obligation of scientists to convince the next generation to take up research careers, and this must be explained to begin-

ners in simpler language;
- the spiritual role of science and scientifically-based technology together with objectivity of science are important for all of society;
- it is important to uncover the pseudoscience that gives populistic and false explanations about the natural world;
- last but not least, doing science is creative and the emotions and fun involved in scientific discovery should be shared with others.

There are two avenues to popularization. First there are many well-known publications and video materials on many topics explaining complex things. Authors like J. Gleick, S. Hawking, R. Dawkins, R. Penrose are just a few to be mentioned. These brilliant expositions of complicated scientific problems and discoveries should be available to all and translated if needed. The second avenue should be pursued locally through science museums, science days and publications by scientists in every country, large and small. This illustrates to the local community the results to be gained from taxpayers' money (cf. reasons given by Maugin, 1992). And it is not only an abstract community of taxpayers. One should stress that such activities are extremely important in small countries because shortsighted politicians and even parts of the scientific community think only in terms of everyday needs, mostly based on a cash-in-cash-out principle. The reasons for this are usually based on stressing the smallness of the country. This often contradicts quality requirements that are imperative to successful research.

Final remarks

Countries are all different – shaped differently by geography, history and other factors. The attempts to mould them all – large and small – into a rigid system are blind alleys from the very beginning. Flexible networks and systems are much more effective: they are dynamic, they keep developing, elements can easily be rearranged or replaced, critical mass of smaller units can be compensated by larger units, etc. All that works in favour of quality.

Lord Rutherford has said in Cavendish: "We haven't the money, so we've got to think." My comment to that is – there will always be too little money and we all have to think more. The fruits are visible – mapping the human genome, nano-materials, fast computers, and much more. This is the charm and also the burden of contemporary world.

Weiner (1999) has listed several fundamental 'experiments' going on. These are human population explosion, global warming, the progress of technology, and the process of evolution. In addition there is a dream or hope, according to E.O.Wilson that everything we know about man and universe will fit in a general vision. Probably the most important question is still how we can cope with all that? This is a challenge for all the world and in this, large and small countries should unite their wills and potentials.

In this essay the concept of fractals has been used to stress the idea of networking, which is so important for smaller countries. The simple rule is – support quality. Certainly, ideas born in mathematics or physics may not be directly applicable to other fields of knowledge. However, Mainzer (1997) has used concepts like attractors, bifurcations, stability, etc. to describe developments in science and technology. With such an understanding, it is much easier to describe complex systems where the pyramidal concepts are too rough to explain complicated links. The notion of fractal networks gives a useful way of thinking about science and its structures which is the endless frontier that Vannevar Bush has carved in stone tablet.

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