Innovation and Research Systems[1]

Future Challenges for the knowledge infrastructures of EU candidate countries

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[1] The views expressed in this paper are not necessarily those of the European Commission

Introduction

The coming ten years will provide a period of possibly unparalleled opportunity for renewal in the science and technology (S&T) base and the building of necessary knowledge society capacities and capabilities in candidate countries. The drive towards restructuring and modernisation of innovation systems at the national level is taking place against a shift of gear in the development of European S&T with the launch of the European Research Area. The possibilities for synergies and an opening up of national systems provides a one-off chance for the Pre-Accession Countries (PACs) to find a fast track towards full integration in the European research and knowledge system.

For many PACs particularly the Central and Eastern European Countries (CEECs) there is a serious opportunity to build on a long tradition of high quality fundamental science. However turning the opportunity into reality presents great challenges. The period of transition has eroded the stability that S&T needs in order to flourish. In addition, the existing S&T capacities are not necessarily appropriate to the achievement of high rates of innovation.

In this paper we try to analyse some of the main challenges that PACs face, as they try to establish a knowledge infrastructure fit for the future.[2] We do this by addressing four main questions. What do we mean by a knowledge infrastructure? What is the current status of the Knowledge Infrastructures in the candidate countries? What seem to be reasonable targets for development? What pathways seem open for achieving these targets?

What do we mean by a knowledge infrastructure?

For pre-accession countries the transition towards knowledge-based economy and society is essential for their full integration into the European economic area and the European society as a whole. The need for higher economic growth, competitiveness and sustainable development puts a special emphasis on the knowledge infrastructure in these countries.

The knowledge infrastructure is made up first of the research centres that constitute the institutional supply base for knowledge-based economy. Second there are the knowledge transfer centres and the organisational capacity to undertake innovation at industrial. Third, and equally important, there are the people themselves that give life and motion to the knowledge society. For this paper we will limited the analysis to the main building blocks of the Research, Development and Innovation (RDI) system – research units (research institutes, public laboratories), universities (and other educational and training institutions), enterprises (branch and industrial R&D) and intermediaries (bridging institutions, technology transfer organisations, patent offices) and the links between them. The objective for building a more effective and efficient knowledge infrastructure in candidate countries is considered in regards to the requirements for:

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[2] This paper is drawn from the work undertaken for the Enlargement Futures Project of the IPTS and presented in the report Expert Panel on Technology, Knowledge and Learning, JRC/IPTS EUR-20118. We gratefully acknowledge the contributions of our co-authors James Gavigan, Fabiana Scapolo and Paola di Pietrogiacomo and of all the experts that helped us to compile that report. The report can be downloaded from http://www.jrc.es/projects/enlargement.

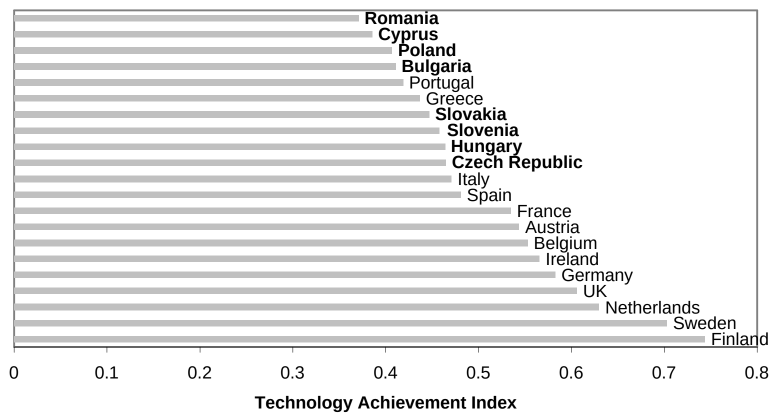
- A coherent R&D and innovation system;
- Strengthened partnerships between research, universities and industry;
- New infrastructure resources and intermediaries to facilitate technology transfer;
- Emergence of relevant knowledge intensive services;
- Increased openness to international networking.

Analysing the recent development of the knowledge infrastructure in candidate countries, this paper seeks signs of emerging models of research in PACs and the respective future ofknowledge institutions.

What is the current status of the Knowledge Infrastructures in the candidate countries?

Recent data giving an aggregate comparison between some PACs and current EU members paints a positive picture, suggesting that the PACs have the potential to sustain high-level research systems, at least on a par with several of the EU15 (e.g. Fig 1).[3]

Figure 1 Comparison of PAC and EU States' Technology Achievement



However, the research systems have undergone substantial restructuring in recent years. Although PACs have been following different tracks as regards the development, the CEEC candidate countries mostly applied heavy cutbacks on industrial research with

[3] The UNDP's technology achievement index aims to capture how well a country is creating and diffusing technology and building a human skill base - reflecting its capacity to participate in technological innovations of the network age. This index is a composite of four dimensions including technology creation (patents granted to residents; receipts of royalties & license fees), diffusion of recent innovations (internet hosts; high & medium tech. exports), diffusion of old innovations (telephones, electricity consumption) and human skills (years of schooling; output level of skills & qualification, tertiary professional and scientific education enrolment and graduates' ratio). United Nations Development Programme (2001) *Human Development Report 2001*, Oxford University Press, New York/ Oxford

many sectoral research institutes being heavily downsized or closed (see Box 1). The process of transformation of the sector has followed three phases[4]:

- Dissolution and fragmentation of the old S&T systems;
- Restructuring, consolidation of institutions, emergence of new organisations;
- Building of a new innovation system through integration and networking.

Thus, while the data in Figure 1 certainly do give grounds for hope, it would be premature to assume that much of the work of reconstructing the knowledge infrastructure has been done. National circumstances differ, but most of the candidate countries have completed the first two phases but the third phase still lies ahead.

Box 1: Approaches for the restructuring of the R&D system

Dyker and Radosovic[5] point out that the patterns of restructuring in industrial science base have been quite different from place to place. A few countries have engaged in an active restructuring, such as Slovenia and Poland, with attempts to ease the process of change, with co-funding, innovation policies and so on. Some CEECs such as the Czech Republic, Estonia and Latvia allowed industrial research to suffer the shock of a rapid transition to a private sector model. Whilst, probably the most common approach, such as in Hungary, Slovakia, Romania and Bulgaria, has been to let the research institutes struggle along with reduced public funding and state contracts but no active support to restructure.

The ***Latvian*** approach[6] in restructuring R&D is based on the integration of the national research potential into universities with the aim of modernising the universities and strengthening their research capacity. Research centres of national significance have been established, selected on the following criteria:

- high international recognition;
- consistency with national research priorities;
- well developed international collaboration in research and training;
- advanced and innovative performance.

In the ***Czech republic***, in comparison, no structural policy has been carried out at microeconomic level within the R&D system.[7] The government had withdrawn financial support from the majority of industrial R&D institutes at an early stage in the transition process and during the privatisation they have been treated as 'normal' production enterprises. This shock without therapy has led to the conversion of the activities of R&D institutes to production and services.

Industrial research units

The R&D institutions that have survived to the present day are self-governing and autonomous, breaking with the state control of the past. However, the decline of financial support by the state and the inability to attract other funding confront most of them with growing problems of preserving their research capabilities and carrying out world-class research. The passive policy of some governments towards restructuring of the academic institutes has had the transitory advantage of preserving some jobs. And, the stagnation of research capabilities might have much bigger long-term consequences. Only in Romania

[4] Meske, Three phase model, Science and Public Policy, 2000
[5] Dyker and Radosevic, Building the knowledge-based economy in countries in transition, http://www.sussex.ac.uk/spru/
[6] Prospective Dialogue on EU-Enlargement: Science, Technology and Society, Berlin, 1999
[7] Innovation policy issues in six applicant countries: The challenges, European Commission, DG Enterprise, 2001

and Lithuania have significant applied research capacities survived, at least up till 1999[8], but there is a concern that much of it is inappropriate to a 21st Century knowledge society. In the others, notably the Czech Republic, capacities are being revived progressively.

The main problems relate now in all PACs to the fragmentation of the RDI system, based on the lack of co-ordination and interaction between the main actors, and thus its insufficient efficiency[9]. Science and research, and technology and innovation are not considered holistically. The fragmentation of the whole RDI system is exacerbated by splits between ministerial responsibilities and the following lack of horizontal co-ordination and interaction between all actors.

Although widely discussed in policy documents, the need for enterprises to establish closer co-operation with research units and to increase their financial contribution to research, practical results are still low. Moreover, business investment in research has been very low in almost all PACs (except the Czech Republic, Slovakia and Romania). The history of central planning and the reliance on public funding sources have inhibited the growth of business-research linkages, and this contributes to the difficulties that public research institutes face today. In Poland, industrial research has played only a minor role in the institutes of the Polish Academy of Sciences, which have focused mainly on scientific collaboration with other research institutes on basic science. Specialised R&D units in Poland have relatively better interactions with industry, mainly in the technology and product development, but even here passivity rules[10].

Branch research institutes have stronger and more differentiated interactions with industry in the past. But they are affected by the cutting of state support and the drying up of industrial funding during the restructuring. Branch institutes had severe difficulties to retain professional equipment and their best staff. The inability to finance longer-term research and their present focus on short-term services, as well as the lack of consultation with industry on choosing industry relevant research topics, might further prevent the establishment of closer collaboration.

The natural partner of applied research is of course the industrial demand for S&T outputs. Here however there is a lack of effective demand for local S&T capacity. Multinational investments in PACs are mainly in forms of manufacturing that do not call on local research capabilities. Research facilities are normally in the headquarters of multinational companies and there is little exploitation of local research expertise. Only a few large companies, still state-owned or already privatised, retain R&D units.

Presently, the main mechanisms for technology transfer in candidate countries are mostly indirect such as:

- Inward transfer of ‘hard’ (product, process) or ‘soft’ (management) technology, mainly by foreign direct investment (FDI);

[8] See the report "Impact of the enlargement of the European Union towards the associated central and eastern European countries on RTD-innovation and structural policies" DG Research, European Commission (1999)

[9] Impact of the enlargement of the EU towards the associated CEECs on RTD-innovation and structural policies, European Commission, DG Science, Research and Development, 1999

[10] A. Jasinski, Academy-industry relations for innovation in Poland, Steep discussion paper No.41, http://www.sussex.ac.uk/spru

- Integration of local firms into the international production chain by subcontracting, outsourced assembly processes, provision of distribution services, reverse engineering of products and/or customised production and design;
- Co-operative industrial alliances with foreign partners and learning-by-trading.

Direct technology transfer is limited to interchange of personnel (spin-offs from research units or researcher-led start-ups) and is rather small scale. Domestic firms, meanwhile, tend to be either smaller or in lower technology sectors so their call on S&T services is less significant.

Generally, limited financial resources and low revenues prevent domestic companies to fund their own research or access other R&D results. The enterprises in Turkish pharmaceutical sector, for example, have low R&D capacities due to the small production volumes and the price regulation in the sector. Their R&D activities comprise mainly research related to licenses or production problems. Any investment in long-term research in developing new biotechnology applications for pharmaceutical products, even though they have a big potential, has been limited[11].

On the other hand, there are efforts from domestic enterprises and SMEs to apply advanced research results to gain niche market shares and thus competitive advantages. Despite the high costs of the services of private commercial firms and foreign consultants, domestic companies in Hungary rely on collaboration with foreign laboratories for quality upgrading activities, product development and testing[12]. There are some grounds for hope. The traditional collaboration with domestic partners may be re-established if they overcome the problems of understanding the real industrial needs and improve the quality of their services. Companies appreciate the value of individual researchers and prefer to hire their services on part-time basis, rather than to establish co-operation agreements with R&D institutes[13]. While, some of the domestic enterprises rely on their own research capacities in engineering, product development and design.

University research

One of the hopeful signs emerging from the period of restructuring has been the emerging role of universities as centres of applied research. Due to their role as educational and training centres preparing the future high-skilled workforce, the immediate impact of transition was often not as acute as in the applied research units. The new framework for education in CEECs has facilitated the establishment of private universities, many of them specialised in certain domain relevant to the economic needs. Moreover, development towards world-class higher education has been initiated, through participation in international networks such as joint research projects and student exchange schemes.

Economic expansion has fostered the re-establishment of industry-university links, focused on building high-skilled specialists and managers. In most PACs the interaction of industry and higher education establishments has been extended from sponsorship at the beginning to closer collaboration for developing joint courses and programmes, training materials as well as carrying on research. This type of initiatives, as well as the

[11] BASAGA, H. ve ÇETINDAMAR, D. (2000), Competitiveness strategies: Biotechnology report, TÜSIAD

[12] H.Romijn, University of Oxford, Technology development in transition – the case of Hungarian industry (1998)

[13] The European innovation trend chart, University of Manchester (2000)

on-the-job-training of students, is creating a positive loop, in that industries are beginning to sponsor the education of future employees. Moreover, the on-going collaboration for setting-up laboratories and technology centres at universities is likely to continue to deepen the industry-university interactions also in research.

A number of examples of industry-university relations in PACs point out the establishment of the universities as important centres for both, research and training. At the same time universities seems to be a preferred partner for the industry for carrying out contract research. In particular, some technical universities (e.g. in Hungary, Bulgaria, Estonia) have long traditions in this area and are on the way to re-establish and widen them. In Hungary different foreign companies (e.g. Ericsson, Nokia, Sony, Knorr-Bremse) are involved in joined activities in research labs at the Budapest Technical University in telecommunications, electronics and automotive engineering.

Universities have formed their own centres for co-operation with the industry (box 2). The flexibility of the university management and they self-governance facilitate the establishment of spin-off firms for commercialisation of research results. The involvement of universities[14] in common activities with the newly created spin-off firms, e.g. the participation of professors in business activities and the engagement of students as trainees and workers, is fostering the research-industry relations, as well as the further development of applied research in PACs.

Box 2: University centers of research

In Estonia the integration of research at university has significantly strengthened the research capacities and intellectual resources of the universities. The *Tallinn Technical University (TTU)* has combined bottom-up and top-down approaches in extending its industry relations.

Throughout several years TTU has carried out contract research on behalf of large infrastructure companies in the areas of electricity production and distribution and oil shale mining, as well as with manufacturing companies in the fields of signal processing, electrical equipment and power electronics, automotive industry, etc.

In the field of telecommunication, TTU has started long-term co-operation with the Estonian Mobile Telephone Company and Ericcson Eesti AS., launching a testing and training laboratory.

The co-operation of TTU in chemical technologies with a manufacturer of rare earth metals (AS Silmet Grupp) includes mainly technical consultation and technical information exchange, but is considered to be extended to contract research in coming years.

In addition to the contracts with local companies TTU performs contract research for foreign companies as well. Current contracts include large multinational concerns (like Nokia), but also small companies (Fincitec in Finland) and ranges from sectors such as chemical technologies, material technologies to information technologies and telecommunications.

Considering the important role of competence centres and innovation support structures for the knowledge transfer, a Tallinn Technical University Innovation Centre Foundation was founded in 1998 to connect R&D data of the TTU with technological needs of industrial enterprises.

The range of activities of the TTU will be extended with the establishment of a graduate school. This is considered to contribute to the concentration of the existing resources and the improvement of research training.

(Rein Küttner, Panel member)

[14] Tartu University and Tallinn Technical University in Estonia, Warsaw Technical University.

Although a number of government initiatives have been launched in the last few years to foster interactions in S&T development, at institutional level one of the challenges is still related to the linking of R&D institutes, universities and industry. The teaching activities of researchers, both at universities and at research units, the involvement of professors in research projects, the collaboration in scientific events and programmes are part of the new type of co-operation in the RDI system. However, these interactions are mainly at the individual level without establishing tighter institutional links (except where the research institutions have been integrated into universities following an active R&D restructuring policy).

New intermediaries & innovation networks

The need for building bridges between research and industry has lead during the past few years to the emergence of a range of new institutional structures (state or private supported bridging elements) in most pre-accession countries:

- Infrastructure units (parks, incubators);
- Organisations for innovation support of consulting character (innovation relay centres, Euro-info centres, technological centres, specialised consulting companies, foundations).

Set up by government bodies, researchers or NGOs, the new intermediaries represent an enormous concerted attempt to establish new models of international, regional and national co-operation of business and research. The range of activities of the new intermediaries cover a wide range of knowledge-intensive services – provision of information and consultation, ICT support, organisation of training programmes, assistance for finding partners and joint projects, dissemination of advanced technologies, channelling innovative ideas & inventions and support in the protection of intellectual property. However, the development of intermediaries is heavily dependent on the existing financial resources. After the end of the initial public or international funding a number of them face the dilemma how to survive in the market-driven environment.

Candidate countries are starting to pay attention also to clustering and supply-chain networks effects as key components of regional innovation systems. Hungary is considered the most advanced in this respect, but more diversity has been achieved in Poland. In Slovenia industrial R&D clusters are emerging around the two major cities. Estonia is following a Scandinavian model of innovation support and is beginning to develop science parks around the universities. With support from the Phare programme, the traditional Czech focus on research is giving way to a greater emphasis on the interface with industry, while in Cyprus support is also being given to high-tech incubators and other mechanisms to encourage spin-offs.[15]

The establishment of international and regional networks and carrying out common projects with foreign partners is one of the ways for many research units in PACs to overcome the domestic problems for high-level research. International co-operation and academic exchange programmes are widely used as opportunity for increasing the qualification of professors, researchers and students, for development of European research standards in PACs. Through various EU programmes[16] PACs have joined wide European networks, e.g. Euro Info Centres, Innovation Relay Centres, Business and

[15] http://www.cordis.lu/itt/itt-en/01-2/dossier.htm
[16] Fifth Framework Programme, Tempus, Socrates, Leonardo, Phare, etc.

Innovation Centres and Centres of Excellence. International networking is fostering the S&T development in PACs, the transfer of know-how from EU member states, as well as the building of new bridges between the research units and the SMEs in PACs and those in member. In longer run it could facilitate Europe-wide scientific integration.

What seem to be reasonable targets for development?

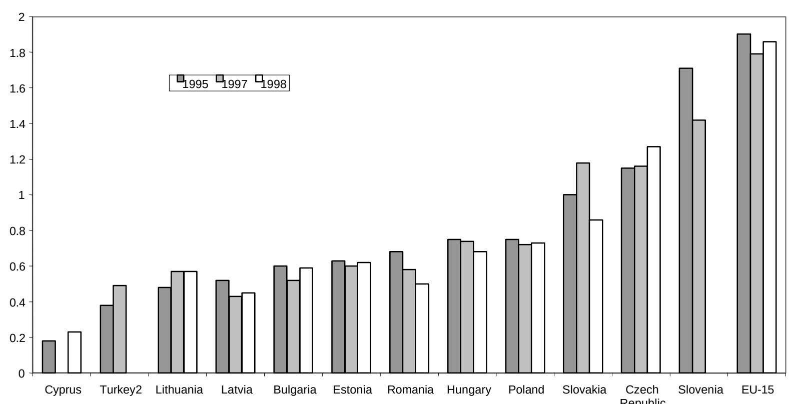
The knowledge infrastructures in Candidate Countries have undergone major changes, and even so they still face further challenges in all areas: fundamental research, industrially driven research and problem-focussed research.

For fundamental research we face the questions:

- Whether it is possible to maintain and enhance high scientific output and in what areas?
- What investments are required in equipment and facilities to allow cutting edge science to continue?

Fundamental scientific performance certainly appears as a priority in the National S&T Plans.[17] They are either acknowledged in a generic way (Estonia) or in terms of explicit but broad general priorities (Czech Republic - several areas of natural sciences; Romania - space research; Hungary & others - national heritage and identity). This is in line with a wider perception that fundamental research is vital across the whole spectrum of knowledge creation and investigation. But, science driven approaches require openness to diversity, high-risk and long-term ideas stemming bottom-up out of scientific communities. In particular, there are many areas in which the scale of investment in scientific infrastructure calls for modes of co-ordinated approaches (international networking, large-scale projects). Explicit and detailed prioritisation is needed in order to make sure that the implications of entering into the long-term support for these fields of

Figure 2: R&D as % of GNP



Source: Eurostat (1) 1992 (2) Statistical yearbook of Turkey (1999) (3) 1994

science (rather than others) are well understood. For example, big science facilities (particle accelerators, synchrotrons, radio telescopes or shared Internet infrastructures for

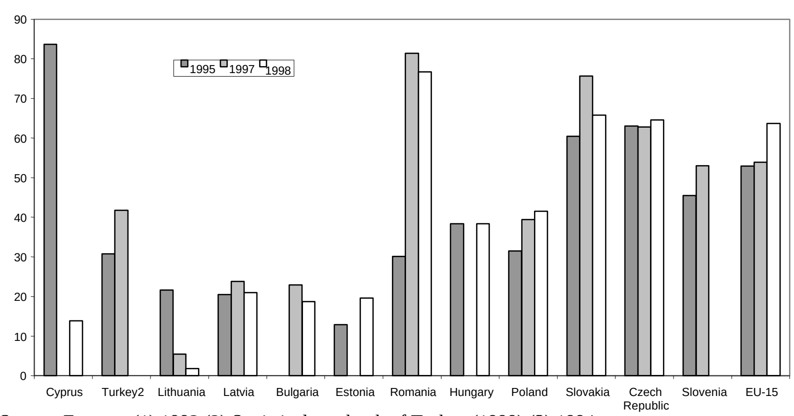
17 Appendix I of the draft Working Paper on 'Knowledge, technologies and learning', http://www.jrc.es/projects/enlargement/, Enlargement Futures

e-Science) may not be achievable by countries or institutions acting alone. It can also be necessary to prioritise efforts aimed at raising the effectiveness of networking in emergent areas of research to create viable levels of research interaction and support for nascent or widely dispersed research communities.

As regards industrial research, the main challenges relate to renewal, following the collapse of industrial research activity and the privatisation of public enterprises. It has been said that it has been hard for decision-makers in PACs to focus on measures to support the creation of innovative start-up firms at a time when many of the largest employers were going bankrupt. The need to deal rapidly with a large number of urgent legislative and policy changes, such as carrying out comprehensive health and social reforms has made it hard for PACs emphasize the apparent luxury of building a knowledge-based society. Although the investments in education and research may give a higher rate of return[18] than public welfare spending or infrastructural development, the available funds for R&D are very limited and a serious decline of the R&D budgets in the transitional period have been observed in all CEECs. The position now in most PACs, is that gross domestic expenditure on R&D (GERD) is significantly below the EU15 average of around 2% (Figure 2). Several PACs achieve roughly equivalent levels to some EU member states at around but mostly below 1.5% (Slovenia, Czech Republic, Slovakia). Then there is a cluster from about 0.8% to 0.4% (Poland, Hungary, Romania, Estonia, Bulgaria, Latvia, Lithuania and Turkey) followed by Cyprus at 0.2%.

At the same time, industrial investment in R&D is generally lower than the EU15 (Figure 3). This is of course significant in that big enterprises play a key role in innovation, in terms of both in-house and sub-contracted R&D. Large enterprises are considered as

Figure 3: Business R&D as %



Source: Eurostat (1) 1992 (2) Statistical yearbook of Turkey (1999) (3) 1994

generators and absorbers of R&D, investing in R&D themselves and helping to maintain the level of market demand for R&D. There are some remarkable exceptions to the low contribution of industrial R&D, Romania, Slovenia, Czech and Slovakia being comparable to the level in EU members. But elsewhere, the private sector contribution

18 Human capital investment, OECD, 1998

seems very low.[19] Moreover, a question exists, whether the statistical data really reflect the situation, and whether the companies, in particular SMEs, are motivated to report any costs made for research rather than just as product costs[20].

In CEECs the economic transformation, in particular the privatisation of state-owned companies and hence the shrinking of R&D budget, has heavily affected the existence of the applied research. After the privatisation of the enterprises, spending on local R&D seldom increased. Independent major companies frequently disappeared after the privatisation and became either subsidiaries of multinational corporations or their specialised suppliers or service providers. These reflected in their low spending on local R&D. The result of all these trends was (with few exceptions) a growing dependence of R&D on governmental and international financial streams and lack of economic relevance.

The urgent need, therefore is to redress the balance in the R&D systems and to increase or further adapt applied research to serve the needs of a technologically advance economy. This cannot be done in a generic way but needs to single out some specific problem-focussed priorities. As in fundamental science, advances here are occurring at an accelerating pace and even in the most advanced countries, making progress and keeping up to the state-of-the-art is increasingly contingent on the concentration of resources on fewer and fewer priorities in areas of existing capacity or achievable capacity. For PACs, this prioritisation task also applies but is complicated by the more basic "catch-up" need to (re-) establish critical competencies and capacities in the key areas chosen, compensating for the ten-year applied research and technology slump.

As regards existing it is very difficult to discern from available information the existing levels of S&T competencies and capabilities in the different countries, and the extent to which the level of research in the different areas justifies investing or earmarking resources. This information is a vital precursor to future prioritisation strategy setting.

An essential early step in this process would be the benchmarking of the supply side of S&T competencies. For example, a recent study of innovation in six candidate countries (Cyprus, Czech Republic, Estonia, Hungary, Poland and Slovenia) found a relative absence of robust data on innovation performance in these six candidate countries suggesting that policy choices are being made on the basis of very partial and non-robust indicators. [21] Therefore, benchmarking is expected to raise many difficulties given that it is composed of a complex-array of expertise and resources including:

- Individuals (eminent scientists, professors, practitioners, inventors...)
- Research & development teams & groups (specialist expert teams whether in public or private insitiutions, laboratories)
- Institutions & organisations (this could be Universities, or faculties within universities, public research organisations, branch-research organisations, private consultancies, companies etc.

19 Cyprus data swings so wildly that the level of confidence we can have in it is quite low.
20 Balint Domolky, Panel Member
21 European Commission DG Enterprise ‘Innovation policy issues in six applicant countries: The challenges’ July2001

- Networks (of either individual scientists, of teams or organisations) at local, regional, national and European/International levels

Such benchmarking is very difficult, but also extremely politically sensitive, especially given the problems to arrive at reliable judgements. For example, excellence and competence is as much a product of factors such as social and cultural resources, organisational routines and ways of doing things, as it is of individuals.

In all cases, it is significant and important assessing what constitutes existing capacity, what is capacity might be achievable and what capacity lies dormant. This assessment of capacity can be assessed against a number of different criteria and can indicate whether the investment might pay off in terms of returns at the national level.

- How does it compare with world class performers in the area? And what would be required to achieve comparable performance?
- Is domestic demand sufficient to support a high quality research capability?
- Could domestic research capacity eventually access international markets?
- Can the activity achieve sufficient critical mass in order to be sustainable?
- If not, can national efforts integrate into larger transnational efforts?

As an example, a lot of encouragement has been given to develop high-visibility and high-performing centres of excellence in several PACs (sometimes through the EU's Fifth Framework Programme). Estonia, for example has focused policy on the fostering of centres for strategic competence at the Universities of Tartu and Tallinn Technical in the fields of biotechnology, information technologies (IT), materials and environmental technology (e.g. the Regional Centre of Excellence in New Functional Materials at Tartu or the Centres of Materials Science and Gene/Biotechnology at Tallinn). These can be seen as *Achievable Capacity*. Alternatively, already in 1996, a review of industrially oriented research capacity identified 15 units possessing a unique position in Poland, 21 units whose activities could be taken over by other units, and 18 units whose existence could not be explained[22]. This is more in line with the assessing *Existing Capacity*.

Table2: PAC Centres of Excellence		**S&T Areas**							
Rank	**Institute**	**Biosci**	**Medical**	**Environ.**	**Engineer**	**Materials**	**Physics**	**ICTs**	**SocEcon**
1	Institute of Genetic Engineering *Kostinbrod, BULGARIA*	X							
2	Czech Technical University in Prague, Faculty of Electrical Engineering, Department of Cybernetics-*Prague, CZECH REPUBLIC*							X	
3	Collegium Budapest, Institute for Advanced Study-*Budapest, HUNGARY*								X
4	Hungarian Academy of Sciences, Institute of Experimental Medicine*Budapest, HUNGARY*		X						
5	Polish Academy of Sciences, High Pressure Research Centre-*Warsaw, POLAND*						X		
6	Estonian Biocentre-*Tartu,Estonia*	X							
7	Institute of Solid State Physics, University of Latvia-*Riga, LATVIA*					X			

[22] See the report "Impact of the enlargement of the European Union towards the associated central and eastern European countries on RTD-innovation and structural policies" DG Research, European Commission (1999) page 178.

8	Institute of Experimental Endocrinology, Slovak Academy of Sciences-*Bratislava, SLOVAKIA*	X							
9	Alfréd Rényl Institute of Mathematics, Hungarian Academy of Science-*Budapest, HUNGARY*							X	
10	Institute of Biochemistry and Biophysics PAS-*Warsaw, POLAND*	X							
11	Wroclaw University of Technology, Institute of Production Engineering and Automation *Wroclaw, POLAND*				X				
12	The Jan Zurzycki Institute of Molecular Biology-*Cracow, POLAND*	X							
13	Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences-*Prague, CZECH REPUBLIC*				X				
14	Institute of Fundamental Technological Research, Polish Academy of Sciences, Centre of Mechanics and Information Technology-*Warsaw, POLAND*					X			
15	University of Cyprus, Centre for Banking and Financial Research *Nicosia, CYPRUS*								X
16	Central Laboratory for Parallel Processing, Bulgarian Academy of Sciences-*Sofia, BULGARIA*							X	
17	Polish Academy of Sciences, Division of Food Science, Institute of Animal Reproduction and Food Research-*Olsztyn, POLAND*	X							
18	Polish Academy of Sciences, Institute of Physics-*Warsaw, POLAND*						X		
19	Danube Delta National Institute for Research and Development-*Tulcea, ROMANIA*			X					
20	Institute of Cellular Biology & Pathology "Nicolae Simionescu"*Bucharest, ROMANIA*		X						
21	Centre of Molecular and Macromolecular Studies of Polish Academy of Sciences-*Lódz, POLAND*	X							
22	Institute of Mathematics "Simion Stoilov" of the Romanian Academy-*Bucharest, ROMANIA*							X	
23	"Horia Hulubei" National Institute for Physics and Nuclear Engineering-*Bucharest, ROMANIA*						X		
24	Polish Academy of Sciences, Institute of Mathematics-*Warsaw, POLAND*							X	
25	Computer and Automation Research Institute-*Budapest, HUNGARY*							X	
26	Biological Research Centre, Hungarian Academy of Sciences, *Szeged, HUNGARY*	X							
27	UNESCO Associated Centre of Excellence for Research and Training in Basic Sciences-*Vilnius, LITHUANIA*	X							
28	Institute of Experimental Medicine, Academy of Sciences of the Czech Republic-*Prague, CZECH REPUBLIC*		X						
29	Research Institute for Solid State, Physics and Optics *Budapest, HUNGARY*						X		
30	Centre for Transportation Research- *Zilina, SLOVAKIA*				X				
31	Institute of Oceanology, *Varua, BULGARIA*			X					
32	Institute of Physics, Univ. of Tartu-*Tartu, ESTONIA*					X			
33	Agricultural Research Institute Soils, Water use and Env.-*Nicosia, CYPRUS*	X							
34	National Institute of Chemistry-*Ljubljana, SLOVENIA*						X		
	Total	10	3	2	3	3	5	6	2

Further insight is gleaned from the results of a proposal-based evaluation of centres of excellence in 12 PACs (excluding Turkey) carried out in the context of the international co-operation part of the Fifth Framework Programme[23]. The 'call for proposals' in

23 Mapping of S&T Excellence in Europe, presentation by Barbara Rhode to the "High-level Group of Experts on Benchmarking, Excellence, Co-ordination of National Policies) , 23 November 2000

question specified that centres should bring together theoretical and applied research and cover the natural, social and economic sciences, using, where possible, a multidisciplinary approach. Excellence was measured against a set of six S&T criteria, one social objectives criterion, two economic development criteria, and six resources, partnership and management criteria. A total of 101 out of 185 proposals received passed the S&T excellence threshold criteria, of which 34 were short listed following evaluation over the complete criteria set (see Table 2).

The main implications which were drawn from the results of this evaluation were:

- excellence in life sciences has emerged over the past 10 years
- excellence in physics is in decline: old equipment / leadership of old areas
- mathematics - still excellent, fundamental still, isolated, however big opportunities when linked up with ICT
- investment in environmental research is lacking, as well as in environmental technologies, in particular in energy research
- engineering is floundering without industrial links
- materials research is fragmented without strategies
- qualitative independent socio-economic research is lacking

As regards problem-focussed research, a mapping of existing or potential supply-side capacity only gives part of the picture needed to establish priorities. Also needed is explicit consideration of the future economic and social relevance of research. The risk of a growing mismatch between research activities and industrial and social needs has to be countered. This is seen in some of the national S&T plans where there are references to nationally specific factors such as culture, language, as well as long-term trends that affect national and regional development. Looking at the stated research priorities for PACs, they reflect the same dominance of societal and socio-economic rationales and objectives as elsewhere, in particular the way emerging themes identified through EU Member State Foresight exercises are formulated. However, it is not necessarily the case that the emerging priorities benchmarked from national-level or EU-15 Foresight exercises are appropriate or best for PACs, nor that they apply to an enlarged Europe.[24] Thus it is important to ask:

- Do these priorities correspond to the type of research and competencies really needed? If not, why not and what then should the specific priorities be - in addition or alternatives?
- Do the EU level foresight priorities provide a useful starting point for the PAC priorities? How should they be adapted and why?
- Are there particular S&T themes determined by local conditions, specialisation, geographic specificities that are generally relevant to transition countries but not necessarily to other European countries?

[24] Some national R&D plan priorities are very close indeed to the foresight priorities, e.g. Romania - complex systems for environmental management, micro & nanotechnologies, natural or created risk prevention, protection & rehabilitation, food security.)

What pathways seem open for achieving these targets?

In this section we explore two important pathways forward. First, the deep structural changes that PACs have confronted in the past ten years pose significant challenges to systems of governance, including S&T. More open systems of priority setting can help to build a widely shared and realistic analysis of the specific situation and what to do. Second, the scope for the emergence of new structures and actors in the knowledge infrastructure can help to widen the effectiveness of innovative activities.

Open and transparent priority setting

Governance issues affect two related but conceptually different areas of S&T[25]:

- To achieve effective and open management and support of a scientific infrastructure and with the selection and evaluation of scientific programmes;
- And to implement good practice in respect to the specification and implementation technical standards [26].

These efforts by PACs to achieve such transformations in S&T governance take place against pressure to fall into step with EU practices, which stress the need for transparency & openness, participation & inclusion, accountability, effectiveness and coherence.[27] This is an area of high policy attention due to rising concerns that the public is politically apathetic and has lost confidence that policy is able to find solutions to major problems confronting our societies.

For all the PACs the next few years will be ones in which it will be necessary to pursue a strategic pathway towards modernisation. It is necessary to be selective on which areas to really excel, which are just plain necessary and from which areas to maintain a low profile or to withdraw altogether. These considerations form part of a strategy of specialisation on the basis of international synergies as well competitiveness. These tough choices are not just for PACs. They form a central theme of the policy framework of ERA. Today even the wealthiest economies can no longer pursue a fully comprehensive range of S&T options to the highest level. But the prioritisation task for PACs is complicated by the more basic "catch-up" need to (re-)establish critical competencies and capacities in the key areas chosen, compensating for the ten-year applied research and technology slump.

It is clear PACs need to follow a prioritisation strategy that closely couples to specific national considerations (physical resource endowments, geographical location, building on traditional areas of competence, increasing the technological intensity & re-awakening the demand for R&D of indigenous businesses).

Most national programmes reveal a strong continuation of supply side driven priorities (i.e. scientific and technological opportunity and interests) including emergent ‘hot themes’ such as biotechnology, nanotechnology and quantum computing as well as long

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[25] See ‘Science and governance in the European Union – A contribution to the debate’ edited by Iain Shepard, JRC-ISIS (March 2000) http://www.jrc.es/sci-gov/docs/scandg-v3012.doc

[26] Technical factors are for instance pollutant limits, pharmaceuticals licensing, vehicle safety standards, etc.

[27] White Paper on European Governance the European Commission COM (2001) 428 final

term standards especially information technologies (wireless communications, embedded systems, artificial intelligence). In some cases we questioned whether the priorities selected correspond to the type of research and competencies really needed in PACs or whether they are earmarked more as a matter of national pride because they are cutting edge areas. In particular, we have not yet been able to relate levels of investments in research competencies to the identified priorities. We suggest greater transparency between priorities and resources in order to send realistic signals about the hard choices that are taken when budget allocation is made.

Meanwhile, many national S&T plans also do include issue driven priorities although it is often not clear how they are established. The issues are often country specific and include ageing population, knowledge society technologies, specific environmental protection demands (coastal margins, natural resources and renewables), cultural identity, linguistic and heritage factors.

The central challenge therefore concerns the ways in which the demand and supply of S&T are balanced. On the one hand, a stable and high level support for fundamental science is needed in order to develop a self-sustaining S&T system. But, not all areas can be supported. The choice what to support should be driven by analysis of existing and potential excellence and its relations to specific demands of the country. Such decision making requires the support of detailed benchmarking of existing performance, and an open process of debate on the identification and setting of priorities and the development of a long term and strategic view of S&T as part of national positioning in its wider context.

However, our investigation of the stated research priorities through published national policy frameworks indicated a close mirroring of priorities that are found in across EU Member States and at European level in the Framework Programme. Perhaps, a need to lever access to extra resources and the absence of the analytical base for decision-making drive PACs (as indeed also happens in some present Member States) towards aligning national technological priorities with those of the EU RTD Framework Programme in order to access funding. This of course has many benefits (better integration into EU-wide research system and networks, high-level technological co-operation and exchange, etc.) but a danger exists that national priorities not reflected in the Framework programme are pushed aside.

One important component of a resolution to such problems is the construction of a clear view of way ahead (where we are, what we are capable and where we want to go). Traditionally such decisions are driven by sectoral or ministerial agendas rather than by an open mapping with a wide group of stakeholders. The institutional fragmentation is both cause and symptom of a problem that the major stakeholders in innovation are not integrated in the determination of research and innovation priorities. Governments have traditionally been the main supporters of research and the public sector research agencies remain powerful, while the interests of innovative enterprises have not yet been formed.[28] A central challenge for governance therefore is to balance the supply-side and demand-side interests in setting research agendas, including service sectors and societal interests as well as manufacturing and agriculture. Generally, governments of PACs are aware of the importance of the involvement of industry in R&D and most governments have developed policies that support industrial R&D. But industrialists claim that research

[28] http://www.cordis.lu/itt/itt-en/01-2/dossier.htm

priorities are defined without consultation and are targeted towards topics where funding schemes are available. The voice of societal actors seems even weaker, and less attention is paid to democratic and human needs and to balance competitiveness against unemployment, inequality, sustainability and risk, ethics or the place of women in science. There are however emergent examples of new practices in some countries based on Foresight (Table 4). Such approaches are more crosscutting and longer term and may provide new avenues for developing more effective and transparent S&T governance systems. So far only a few PACs have moved towards such transparency in S&T governance and only in a partial way covering some constituencies (i.e. based on the efforts of one ministry or a sectoral theme). Efforts such as the foresight exercises in Hungary, Poland, Czech and Malta may provide a model for a way forward. But there is still a long way to go to achieve wide acceptance of these more open systems of governance.

Table 4 – National Foresight and planning activities in some PACs

Country	Responsible institution	Mechanism / method	direct link to R&D policy	Time horizon (years)	Follow-up actions / results
Bulgaria	Ministry of regional development	Panels of experts, SWOT analysis, sector studies	no	2000-2006	National plan for economic development
Czech Republic	Ministry of Education, Youth and Science	Panels of experts,	yes	2001-2004	Priorities for oriented R&D
Hungary	Steering Group and National Committee for Technological Development	Panels of experts, SWOT analysis, scenarios, Delphi survey	yes	no data	National innovation strategy
Latvia	Ministry of Economics	scenarios, modelling, SWOT analysis	no	2003-2025	Macro-economic development
Poland	Programme management team (involving members from Ministry of Science, Ministry of Economy, Ministry of Finance, Ministry of Health, Ministry of Ecology)	Delphi survey, Panels of experts	yes	no data	R&D Technical Foresight
Slovenia	Ministry of Economic Affairs	Panels of experts	yes	2010-2015	National development Programme (from 2003)
Turkey	Supreme Council for Science and Technology	Delphi, scenarios, panels	yes	2003-2023	Policy planning

Emerging structures

A second important development is reflected in the growing number of new players, e.g. foundations, non-governmental organisations (NGOs), industrial associations, chambers of commerce, are presently supporting the research and innovation in PACs. Most of them have an active intermediary role between the institutions governing the RDI system, the small and large companies and the research units. Some are going also further – providing knowledge-intensive services and/or trying to solve applied research problems and in particular focusing on the socio-economic demands for research. Through their efforts at networking these actors are quickly able to build research teams on demand. The flexibility for building multidisciplinary teams, involving prominent researchers, engineers, lawyers, entrepreneurs, etc. in a particular project, provide these structures with higher opportunities for success in the dynamic changing environment and the competitions for funding of research and innovation.

Building on further research capacities is related in many candidate countries with the establishment of centres of excellence or centres of competence, in some cases at universities, in others at strong research institutes or newly established bodies. As discussed above, the international co-operation within the EU Fifth framework programme has fostered the emergence of a number of centres of excellence in all candidate countries. The European Research Area provides also for development of centres of excellence at national level and positioning within a single European network, fostering high-level research and more efficient deployment of the limited human and financial resources for obtaining new technological solutions and scientific achievements. At national level, the emerging centres rely on existing and potential capacity. The establishment of a pool of R&D competence to respond to the needs of research by industry, as well as the support of the scientific community, the industry and the state to these structures is facilitating their growth as attractor poles for research in the respective area. Of particular importance is their strong international collaboration with researchers in the same area for establishing pan-European excellence in research.

Concerted actions of all stakeholders in PACs, e.g. policy makers, industrialists, researchers, professors, NGOs, are needed to build a coherent RDI system in which the institutional base is densely interconnected. In this period of structural change there is a widely accepted need to create a conductive environment and foster effective communication between the major actors in the system. Bridging organisations are part of the solution, but they do not substitute the need for intra-organisational restructuring. Bridging functions are most likely to work as complementary functions to restructured enterprises, universities, R&D service companies. While the survival of bridging organisations will require them to evolve a sustainable business model, perhaps as SMEs, with their own specific in-house capabilities, including knowledge transfer capabilities.[29]

At this stage, when old and new structures exist in parallel, it is still uncertain what model for development of research candidate countries will follow. There are real opportunities for PACs to leapfrog the development and to set up new types of research interactions, more appropriate for the demands of the knowledge society. If we consider the present development trends, some important models for research could be assumed for candidate countries:

1) Economic modernisation is driving new industry-university links focused on building the future knowledgeable workforce. This provides an entry point for university-based laboratories and technology centres engaged in industrial support for applied research. Universities also may attract industrial researchers as part-time professors. Personal links between supervisors and graduate researchers who then go on to work in industry will also help. Finally, the good facilities in

[29] Dyker and Radosevic, Building the knowledge-based economy in countries in transition, http://www.sussex.ac.uk/spru/

some universities, in particular high-speed Internet and modernised technology basis of laboratories, are likely to support their claim as to be centres of research in the future.

2) **Centres of excellence** are emerging outside of the universities characterised by strong research teams, young researchers, dynamic professors and close links to industrialists. These centres of excellence provide a creative environment for basic research and generation of new ideas and innovation. Most of them have been established within EU programmes for research and therefore are dependent on international funding and the question is to what extent they can be developed further as centres of national strategic value. Recognition of this possibility by local public and private stakeholders is especially important for this prospect to pan out.

3) **International and regional networking** is increasingly becoming an essential means of staying abreast of research developments and acquiring expertise. Support for common projects with foreign partners can contribute to profiling areas of excellence and competence and could lead to the establishment of regional multinational research centres with international teams actually based in PAC laboratories.

Conclusions

Overall, the crucial issue for further development of the knowledge infrastructure in PACs is to wire up the innovation system by encouragement of interaction between business, educational and research institutions. This requires flexible configurations and direct engagement of industrialists in the process of application of new technologies. It points towards networking of companies, strategic alliances, and multidisciplinary research centres. Given that in many cases they are starting from scratch there may be opportunities for leapfrogging by the creation of new S&T institutions that match the demands of the knowledge society. For example:

- Built-in industry-university links from the start by co-financed laboratories and technology centres. Incentives for private sector researchers to work in higher education on a part-time basis.
- Encouragement of intermediaries such as technology transfer centres, private research foundations, industrial associations, chambers of commerce and NGOs.

Development of poles of excellence in order to catalyse excellence and competence at the urban or regional level, by attracting leading researchers to join forces on projects of regional, national or international importance.

Another clear challenge for the coming years is to rationalise and co-ordinate diverse initiatives currently taken by various ministries to promote industrial R&D, innovation and technological development. This could be supported by the professionalisation of S&T monitoring and evaluation in the form of **innovation policy units**. They would be responsible to assess the performance of current instruments and structures promoting innovation or technological development, using tools such as:

- evaluation and monitoring systems – to measure the effects of R&D investments, to enable policy makers to monitor industrial R&D and their use of public R&D

- unified set of indicators
- tools/ instruments used in PACs for elaboration/ implementation of priorities, development of knowledge infrastructure, learning capabilities
- benchmarking, best practice, impact assessment, transparency of criteria, audit, anti-fraud, code of conduct (ethics in science)

The regular monitoring of the RDI system performance and the inventory of available resources is a foundation to the determining R&D objectives and to the proper functioning of the whole system.

But the fundamental issue is the need for co-operation of the widest possible group of stakeholders (within and among sectors and regions) in preparing long-term innovation strategies and the introduction of various policy measures and instruments. A focus on nurturing foresight activities is a move in this direction. And, although the first steps to carry out prospective studies (in Hungary, Poland, Czech Republic) have been taken in PACs, there is still a need for wide acceptance of the role of foresight to systematise the debate at national level on future prospects and desires related to socio-economic and technological evolution in medium and long terms.

Such developments are particularly promising in that they address actors outside the confines of scientific interests and expert groups. In the most extended cases they avail themselves of a complete range of horizontal communication possibilities. For instance, there is increasing on-line access to local and national information systems in the area of S&T, to the results of research projects and programmes, to science museums, to science festivals and to citizens' juries. All such channels could contribute to the transparency of the research activities and facilitate the communications of all actors involved and improve the performance of the whole RDI system.

Such openness provides the basis for a much broader look at science, in particular focusing on cultural identity and democratisation of science. The development of PAC governance systems takes place at a time when there is a recognised need for a change of image of S&T and the perception of science in society has been also stressed, in particular the popularisation of science between people and how it could help them. Such approaches should eventually allow a more balanced and legitimate system of priority setting and a clearer vision of the road ahead.