Drivers of policies for STI collaboration and indicators

Background Report 1: Key Themes From the Literature

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1. Introduction

This literature review is a background document for the final report of the study on ‘Drivers of policies for STI collaboration and related indicators’. Much of the findings in this review re-appear in a condensed form in the final report. This document is not a deliverable in itself, but provides some further articulation of the themes from the literature which informed the production of the final report. The structure and content of the review was determined by the function it played in the project: it primarily covers drivers and indicators for internationalisation of science and technology. It also provides – as context – some overview of the current developments in international S&T activities. Much has been written about internationalisation patterns and this overview does not claim to be comprehensive. Conversely, the literature relating to some of the specific themes of interest to our study tends to be rather thinner.

In terms of drivers, the review goes beyond the traditional exploration of the motivations of scientists, research groups and firms to engage in international activities and the benefits and challenges of doing so. It also explores the drivers for policy-makers and RTDI funders of various kinds (government departments/ministries, arms-length funding agencies, research foundations etc.) to internationalise their policies, programmes and instruments. These motivations and drivers are not necessarily the same as those of scientists, research groups and firms. To be sure, the latter often drive the former, as policies and programmes are generally responsive to needs and developments in the field. However, at the same time, policies and programmes are catalytic; they can drive internationalisation. Further, there are many motives for international opening and international cooperation that might not be science or industry driven, but driven by mission-oriented/sectoral policy goals such as health, transport or environmental sustainability. International co-operation around those issues is often not considered in overviews on internationalisation of the field. In times of the return of the “mission” (or, increasingly, the “grand challenge”) into STI policy debates at both national and European levels, the interplay of international STI activities and sectoral policy domains is likely to become increasingly important (Aho et al 2006). However, very few studies exist on sectoral international STI activities, and our review is therefore limited in this respect. Finally, the international activities of ministries, administrations and foundations are increasingly part of overall “corporate” strategies, driven by the desire to explore the possibilities “out there”. These strategies react, of course, to developments in the field, but they may, to some extent, follow their own, institutional logic. Again, systematic reviews on strategies of corporate public actors (research organisations, funding organisations) are rare.

The second pillar of this review is a discussion on indicators. Again, this discussion briefly covers the attempts being made to measure and assess internationalisation of the STI community. We then explore what is out there in the literature on internationalisation of STI communities and policies, as a basis for our own country review.

The review is structured as follows: we first explore the internationalisation of science, technology and innovation, and of researchers and research communities, as a general phenomenon. Then we turn to focus specifically on the internationalisation of industrial R&D, before turning to the institutional context of STI, exploring both the internationalisation of national research institutions and that body of international research organisations. In the penultimate section we turn to the international dimensions of STI policies, exploring motives and drivers and mapping also the different policy areas with which these intersect. Finally we explore what the literature says about indicators for better understanding these trends and dynamics.
2. Internationalisation of the STI community

Though science has always aspired to universalism, the growing internationalisation of research is perhaps most visible in the growth of a global science system of English-language journals. Three key long-term trends seem to be at work here. First, the growing trend away from publishing in ‘national’ journals and towards publishing in ‘international’ journals covered by the ISI-Science Citation Index (SCI). Second, the change in emphasis from non-English to English language journals within the SCI journal set. Third, the trend towards publishing in ‘high-impact’ SCI journals (van Raan 1997). Further, within this increasingly globalised scientific literature international scientific co-operation as measured by co-publication by authors from two or more countries is on the increase, and internationally co-authored papers seem to have a higher citation impact (Glanzel, Debackere, Meyer 2006). These phenomena are discussed in more detail below. There are some aspects of internationalisation which raise policy questions however:

First, in an influential early review Frame and Carpenter (1979) identify some ‘principles’ or patterns of international scientific co-operation which still seem to hold fairly true today: For instance, they suggest that the more basic the field of research, the more likely there will be international collaboration. They further note that researchers in larger national systems are driven to look abroad for collaborators less than those in smaller ones. Finally, they stress the important role played by factors ‘external’ to science itself: socio-political or cultural aspects are influential in pushing researchers to collaborate – for instance research collaboration often follows neo-colonial patterns (although most US and European science is conducted with other US and European scientists).1 It is important to remember that there are also differences between/within fields (e.g. humanities and social sciences remain rather less internationalised than natural sciences. Similarly Luukonen et al (1992) identify social, historical, geopolitical and economic factors – as well as cognitive or ‘scientific’ factors – as potential drivers of international scientific collaboration.

Second, there is clearly differential access to the ‘global scientific system’ which has emerged in the last few decades, with particular difficulties for non-English speaking and less developed country scientists in breaking into ‘international’ journals covered by the SCI (Gibbs, 1995). This in itself can be a driver of further internationalisation as less developed country scientists are often forced to seek collaboration with developed country researchers in order to break into the international, English-language journals – this pressure perhaps having unintended impacts in terms of affecting the relevance of research conducted by less developed country scientists for domestic innovators (see e.g. Xue, 2008 on China). This is an important aspect when it comes to S&T cooperation designed to support development policy, an issue discussed further in section 3 below.

Beyond the growth of co-publication and internationalisation of scientific publication and collaboration other factors include increased mobility of researchers and consequent fears about brain drains/brain gains; the growth of international research programmes, facilities and organisations as a result of these trends and as a result of the ever increasing cost-intensity of leading-edge research and the extension of ‘big

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1 Leading some to propose that ‘dependency theory’, which holds that less developed countries are held in structurally dependent economic relationships with developed countries, may be as valid in science as many hold it to be in economic development. For instance Van Raan (1997) notes suggests that the domination of global science publishing by the US and leading Western European nations ensures that other routes to internationalisation – mobility opportunities for research visits, conferences etc, are skewed in favour of the same countries, thus creating structural ‘dependencies’ between the leading scientific nations and less developed countries.
science’ models from atomic energy to astronomy and particle physics into life sciences and beyond.

2.1 Individual researchers

2.1.1 STI Cooperation

2.1.1.1 Indicators used

The indicators most widely developed and used in relation to internationalisation are those that measure the scale and scope of international activity of the STI community. It is important to note that internationalisation policies target the STI community and to improve the nature, conditions and effects of international activities. Therefore these indicators are – more or less consciously and systematically – used to define starting points and targets as well as policy effects.

The first layer of indicators is at the working level, measuring the individual researcher and his or her activity: this comprises international cooperation at project level, international mobility, international knowledge seeking by other means (international databases, literature etc.) and usage and exploitation of knowledge generated in one country in other countries.

By far most work has been done to capture the scale of international collaboration. In terms of academic research, the indicator most often used here is co-publications of authors from two different countries (with co-patenting used to measure application-oriented research collaboration). Analyses explore the absolute levels of co-publication activity, the share of international co-publications of all publications, and the share of international co-publication of all co-publications. An indicator for the scope of internationalisation is the analysis of the (average) number and geographical spread of different countries that collaborate (see also Mattison et al. 2008). Thus, co-publication analysis can tell us something about the relative importance of international collaboration that leads to tangible outputs (publications) and the nature of the cooperation in terms of countries and disciplines (see for instance Adams et al. 2007, Glänzel 2001, Glänzel/DeLange 2002, Schmoch/Schubert 2008, Mattison et al. 2008, Edler et al. 2007).

In terms of application-oriented research, co-patent analysis has been used to characterise the growth of international cooperation and patterns of partnerships (see for instance Cantwell 1989, Guellec and van Pottelsberge de la Potterie 2001, OECD 2008b). The indicator of choice here is co-patenting or co-inventing (although mostly applied at the firm level rather than at that of the individual researcher, see below). Patents are either owned by individuals or organisations in different countries or – more commonly – at least one inventor lives in a country different from the host country of the patent owner (co-inventors rather than co-patent owners, OECD 2008b). This indicator not only enables us to explore the share of research activities (leading to patents) that companies or research organisations do outside their home country or the relative share of activities carried out in a country by foreign companies, but it also allows analysis of co-operation patterns.

Bibliometric and technometric indicator analysis of the kinds discussed above often provide the basis for more complex analyses. These approaches explore variables such as the average inclination of actors from various countries to cooperate, cooperation patterns between countries (and the relevance of country characteristics such as size,
geographical proximity, economic strength, scientific or technological specialisation), differences between sectors, technologies or scientific fields and the relative technological openness of countries².

In terms of effects or impact of international co-operations in science, the most commonly used approach is an analysis of the impact of scientific outputs as measured by citations to those outputs, based on citation counts (comparison between international and national publications) or co-citation analysis (Glänzel et al. 2006, Narin et al., 1991; Lewison and Cunningham 1991; van Raan, 1997; Roberts 2006). Recently Schmoch and Schubert (2008) have raised doubts as to whether the higher citation counts observed for international co-publications are a strong and unambiguous indicator of higher quality, given that higher citation can also be a result of a larger community (based on the international nature of the work carried out). They warn that much caution is required in interpreting this trend because, although there is a correlation between international activity and citation impact, the relation is not strong enough to use international co-publication as an indicator for quality. To complete the picture, a further indicator used is the share of international co-publications in different sets of journals of a specific field (Beaver/Rosen 1990, Gordon 1980), Where the share is seen to be higher in ‘core’ journals than for the average of journals in the field this is taken to suggest a higher quality and relevance of the output.

Beyond bibliometric analysis, further indicators used to explore impact follow traditional assessments of scientific activities more generally, but applied to international projects, such as milestone analysis, technical review of cooperation activities or output and outcome assessment of participants in projects (based on surveys or interviews), which can be both quantitative and qualitative (Wagner 1997).

Table 1: overview of indicators for scale, scope and effects

<table>
<thead>
<tr>
<th>Mode of international activity</th>
<th>Indicators scope, scale</th>
<th>Indicator effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>International collaboration in basic science</td>
<td>Co-publications, number and geographical scope of authors, share out of all publications, field and country/region specific Usage of international research facilities Participation in international basic research (e.g. HFSP) and networking programmes (e.g. COST)</td>
<td>Citation impact of international co-publications (differentiated for country constellations, fields etc.) Career developments of co-operating scientists (CV analysis)</td>
</tr>
<tr>
<td>International collaboration in application oriented research</td>
<td>Co-patenting (co-invention and cross-border ownership of technology) Number of common international research projects, participation in application oriented international programmes (FP, EUREKA)</td>
<td>Licensing income of international co-patents (vs. national only patents) Economic effects (comparison of sectors with different scale of international research co-operation). Improvements in R&amp;D performance of companies (partly qualitative, speed, quality, costs)</td>
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2.1.1.2 Developments

Recent bibliometric studies have disaggregated total research output and identified directly the contribution of international scientific collaborations in science.³ The

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² As indicated for instance by the share for a given country of patents co-invented by a domestic or foreign inventor, the share registered by a foreign applicant but invented by a domestic inventor, and the share registered by a domestic applicant but invented by a foreign inventor (Guellec and van Pottelsberge de la Potterie 2001).

³ The
evidence suggests that collaboration has grown stronger than the underlying volume of scientific output in general (Adams et al, 2007, Adams 2008). Table 1 compares statistics of papers co-authored by scientists located in different countries as indicated by the addresses of their institutions of affiliation for the years 1990, 2000 and 2005. As the aggregate number of outputs grew over the 15-year period considered, so did the number of internationally co-authored papers, as would be expected. The most salient information, however, emerges from the simple computation of relative shares reported in the last column. It indicates that proportionally the contribution to global S&T output of international collaborations increased from 8.7 per cent of total output in 1990 to 17.4 in 2005. Adams et al (2007) and Adams (2008) confirm these developments.

Table 2: Global cross-country collaborations in science 1990, 2000 and 2005

<table>
<thead>
<tr>
<th>Year</th>
<th>Unique documents in SCI</th>
<th>Addressees in the file</th>
<th>Authors for all records</th>
<th>Internationally co-authored records</th>
<th>Addresses, internationally co-authored records</th>
<th>Percent internationally co-authored documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>996,831</td>
<td>1,696,042</td>
<td>3,301,251</td>
<td>171,402</td>
<td>618,928</td>
<td>17.4</td>
</tr>
<tr>
<td>2000</td>
<td>778,446</td>
<td>1,432,401</td>
<td>3,080,438</td>
<td>121,432</td>
<td>398,503</td>
<td>15.6</td>
</tr>
<tr>
<td>1990</td>
<td>690,341</td>
<td>908,763</td>
<td>1,866,821</td>
<td>51,596</td>
<td>147,411</td>
<td>8.7</td>
</tr>
</tbody>
</table>

Source: Wagner and Leydesdorff, 2005

It is thus clear that, whilst science has always been a highly internationalised activity at least in principle, the internationalization of public research is increasing in a dynamic fashion and is likely to continue to increase in importance. Some basic figures from two recent surveys on public research institutes (including universities) and individual researchers in Germany may suffice here for illustration (Edler et al., 2007): The share of international co-publication out of all publications has increased. For Germany, for example, almost 40% of all scientific publications are international co-publications, almost a doubling between 1991 and 2003. The increase is true across all scientific areas except humanities.

The level of international co-publications varies from country to country (European Commission 2003, p. 303 – 304, see Figure 1 below, also Adams et al, 2007). The smaller countries (Portugal, Belgium, Denmark, Austria and Ireland) show the highest share of international collaboration, while some larger countries, mainly UK, US and Japan) are much less internationalised in terms of collaborations. This does not mean that scientists of smaller countries collaborate less in total (domestic and international), but whenever they collaborate they have a much greater need to search for partners abroad. Thus, for Ireland, for example, 42% of all publications are in cooperation with foreign partners, but only 18.2% are with domestic partners. With the advent of more global locations that are accessible and suited for international cooperation, this ratio may further develop in favour of international collaborations. Access to global partners thus is key for scientists especially from smaller countries. Further data compiled by the EU also shows that international collaboration does not concentrate on European partners; in almost all fields the majority of international co-publications entail at least one non-European partner.

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3 This section draws partly on Edler et al. 2008.
4 It must be noted, however, that a limit might emerge in the light of the fact that rate of growth of the share of internationally co-authored papers appears to be decreasing over time.
As stated above, the number of citations received by papers after publications can be used to approximate the level of impact the findings have had among peers. The common trend for almost 2 decades is that by and large internationally co-authored papers are more highly cited than single authored papers or publications based on domestic collaborations (Glänzel et al. 2006, Narin et al., 1991; Lewison and Cunningham 1991; van Raan, 1997; Roberts, 2006, Adams 2008, Adams et al., 2007). Glänzel et al. (2006) analysed citation data gathered for papers among whose authors at least one was located in the US, Europe, Japan or China – the ‘Tetrad’ – Korea, Chinese Taipei, Brazil and Turkey. The figures show that international collaborations systematically display above-average performances. In addition, while for the EU15, the US and Japan, a slight decrease is observed, all other countries in the table register upwards trends. Further, Adams et al. (2007) have shown that the relative performance of international collaboration varies not only across partner constellations, but also across scientific disciplines.

Source: European Commision 2003, p. 30

Superior performance here implies impact in terms of readership. We have already noted that whether this implies research of superior quality is a controversial question.
2.1.1.3 Motivations

The motivation for researchers to engage in international collaboration are manifold, and some attempts have been made to explore these systematically through survey work. It must be noted that the motivations differ by fields; scientists in those fields that necessitate large scale facilities or that are characterised by a high level of specialisation and division of labour are more likely to collaborate internationally than scientists in areas such as humanities, in which national context is more, and international division of labour correspondingly less, important.

The following list attempts to convey what broad consensus exists in the literature on international collaboration about motivations and drivers. However it should be remembered that the relative importance attributed to these motivations by different authors does vary. Amongst the motivations and drivers emphasised in the recent literature (see, for example Georgiou 1998, Archibugi and Iammarino 1999; Wagner and Leydesdorff 2007; Wagner 2006, UNCTAD 2005, Edler 2007; Edler et al. 2008, Beaver 2001) are:

- Access to and acquisition of leading edge and complementary knowledge;
- Access to foreign technology markets;
- Sharing of the costs and risk with international partners, especially when large infrastructures are needed for basic science (e.g. particle accelerators) or product development (e.g. international telecommunication networks);
- Combination of competences and data located in different countries to tackle issues to complex for researchers from one locations;
- Finding solutions for complex scientific and technical problems that could not be solved with domestic resources alone;
- Access to funds from foreign institutions / programmes;
- Access to skilled individuals that might have an interest in pursuing opportunities for research in another country (recruiting);
- Access to endemic research subjects, such as natural or social phenomena, etc. which are limited geographically;
- A desire to influence regulatory regimes or standards;
• Improving the impact and visibility of one’s research (see above).

2.1.2 Mobility

2.1.2.1 Developments and Indicators/measurement

The cross-border movement of researchers constitutes another factor contributing to the growing internationalisation of science and technology. Whilst the migratory flow of researchers (and indeed of highly-skilled workers more generally) is not a recent phenomenon, there is convincing evidence that the mobility of scientists, at least within OECD member countries, has increased (Casey et al., 2001; OECD, 2002a). A large number of one-off studies of researcher mobility (often conducted in the context of an evaluation of a mobility-related funding scheme) exist, but there is comparatively little systematic collection of consistent data about researcher stocks and flows on either a Europe-wide or indeed a global basis. “Researcher” is not an occupational category as coded under International Standard Classification of Occupations (ISCO), presenting significant challenges for data interpretation. Doctoral students are classified under the International Standard Classification of Education (ISCED97), meaning that much of the systematic data which does exist is focused on this category of researcher. However doctoral students may exhibit a wide range of roles and functions in different institutions or research systems, thus raising further challenges in terms of data comparability (RINDICATE, 2008). A number of relevant indicators have been constructed within the IISER (Integrated Information System on European Researchers) project of the European Union DG JRC-IPTS. The IISER indicator set covers researcher stocks, research careers and researcher mobility (intra-EU, into and out of the EU). Many of the indicators specified by IISER remain unfillable by existing datasets and a major new study funded by DG Research aims to fill at least some of these gaps. The indicators specified include the circulation of doctoral researchers within the EU (i.e. inflows, outflows and netflows); outflows to the US (e.g. country of origin of non-US citizen holders of US doctorates; function of non-US researchers in US universities; fields of specialization of non-US researchers in US universities); and inflows of non-EU researchers into the EU (country of origin of non-EU doctoral candidates in EU universities; ratio of third country to non-EU doctoral candidates; etc). Beyond these project-based activities Eurostat and the OECD are working, often in co-operation, towards the development of improved data harmonisation. Since 2005 incoming foreign researchers have been incorporated in Eurostat data collection (such as the R&D statistics questionnaire). Eurostat/OECD and UNESCO are also involved in harmonising national surveys on the Careers of Doctorate Holders: currently 17 countries have such surveys but with various objectives, populations and frequencies which limit the comparability of the data collected (RINDICATE, 2008).

Existing studies do suggest some dynamics and patterns: for instance a survey conducted by MERIT and published in 2002 indicated that the US is the most popular destination for graduates seeking career opportunities abroad due to better salary conditions, prospect of swift career advancement and access to top-of-the-range facilities. The study reported that between 1991 and 2000 three-quarters of holders of doctorate degrees in science and technology of European origins planned to remain in the US. The National Science Foundation (2004) also found that the percentage of foreign born employees with doctorates in S&T reached 30% and that 450 000 members of staff of research institutions came from abroad. As of 2003 (data from the European Commission), in the EU15 area there were a total of 466 000 highly skilled workers employed in S&T jobs employees were of foreign origin and that half of those had come from extra-European countries outside of the EU15.
Further, among the major determinants of the choice of country of migration, language is not surprisingly an important factor\(^6\), together with geographical proximity, links of cultural and historical nature (e.g. old colonial ties such as between France and the Maghreb), the presence of dedicated schemes and the enforcement of favourable immigration policies (DSTI, 2006; Schubert and Glänzel, 2006). Though significant barriers remain (RINDICATE, 2008), overall it may be that barriers to international mobility have been lowered significantly in recent years (or alternatively that ‘attracting’ or ‘repelling’ factors\(^7\) at the source or destination locations have increased). The risk of ‘brain drain’ (see for example the 2006 OECD report on the internationalization of business R&D, OECD 2006a) is much debated, with much discussion of the possible benefits to all parties of ‘brain circulation’ (see e.g. Saxenian, 2002), but analysts and policy-makers alike remain concerned about the possible problematic consequences of outflows of researchers for smaller economies that cannot guarantee top-of-the-range salaries and research facilities\(^8\). There is anecdotal evidence to suggest that mobility can sometimes (and perhaps often) have detrimental effects upon the career progression of individual researchers (RINDICATE, 2008), although other studies (generally based on evaluation of specific initiatives rather than general surveys of mobile researchers) paint a more positive picture. Existing studies have thus failed to fully disentangle the various impacts of mobility on the research done by mobile researchers, on that individual’s personal and family life and career, and on the sending and receiving research groups, institutions, and systems\(^9\).

**Geographical mobility**

The findings of the RESCAR ERAWATCH (Robinson et al, 2007) survey offer some interesting indicators of geographical mobility, suggesting that the world is not a level playing field. The survey focused on university-based research teams in engineering and the social sciences across Europe. It covered 10 European countries: the Czech Republic, Germany, Spain, France, Hungary, Italy, Norway, Portugal, Sweden and the UK, and examined more than 5500 departments from 539 universities. Of these departments 1800 (32%) were classified as social science, 3700 (37%) as engineering and 47 (1%) as mixed social science and engineering.

The survey found that the mobility of young researchers within the EU as well as within Europe in general is relatively low. At the level of PhD students 7.3% were born in another EU member state and another 2.5% in a European but non-EU country. More students from Asia, Africa and Latin America study for a PhD in engineering or social sciences in the 10 countries. The low rate of European PhD students was even more pronounced in the social sciences than in engineering. For post-docs, on average

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\(^6\) Especially for English and Spanish-speaking researchers

\(^7\) For instance access to leading-edge researchers or research facilities, a flexible research labour market and good terms and conditions might be attracting factors whilst their absence might be repelling factors. Clearly wider economic, social and political conditions may also play a role.

\(^8\) The traditional concern of research policy has been with the threats posed by ‘too much’ outward mobility. The more dynamic concept of ‘brain circulation’, from which both the source and destination research system may benefit, has been strongly influenced by the realisation of the subsequent positive role played by Indian scientists and engineers who had emigrated to work in California’s Silicon Valley in the later creation of new high-tech firms in India. However, there remains the potential for negative impacts from mobility, whether felt at the system level, that of the institution or research group or by the mobile researcher themselves. Similarly mobility may be driven by negative developments in the source research system or institution.

\(^9\) Science is an inherently internationalised enterprise and mobility can be driven by more or less pure scientific goals (for instance access to advanced training, samples or research infrastructure – all of which are likely to vary across disciplines or sub-disciplines) as well as career or personal goals. In some circumstances mobility may actually be a contractual or funding requirement. The decision to be mobile then will be driven by a complex mixture of different considerations and incentives, which are likely to vary over time (i.e. from one career stage to another) and from one field to another. Similarly the positive and negative impacts of mobility will be distributed over these different dimensions as well as over time.
13% are from another EU member state and 4% from a non-EU European country: a similar share of post-docs were born in Asia, Africa or Latin America. The UK showed a large inflow of foreign researchers for both PhD and post-doc positions (and also into undergraduate education) and a large outflow when leaving the post (the same for France and Spain in the social sciences). This is an exchange of human capital that should be enriching to the target countries (UK, France, Spain), as they receive able and motivated young researchers coming from a different cultural and educational background who are willing to undertake a considerable effort to increase their knowledge and skills. At the same time, the sending countries – from Europe but particularly from emerging and developing nations from Asia, Africa and Latin America – receive some of the former doctoral students back with a PhD degree and in the case of post-docs even some work experience (though the rate of post-docs who move/return to countries outside of Europe is not too high). In the Czech Republic, Hungary and Portugal (particularly in engineering fields) there are relatively few PhD students who have come from other countries, but many former doctoral students who moved to other countries in Europe. This suggests a loss of human capital after the PhD. As very few foreign post-docs work in the Czech Republic and Hungary, the loss might indicate that insufficient post-doc positions are available. In the case of Portugal, where many (around 70%) of the engineering post-docs have been born in another country, it seems it may be more attractive to go there after the PhD for a post-doc than for PhD education. In terms of discipline, the geographical mobility of former doctoral students differs with regard to both the point in time and the destination chosen: in engineering more students move before entering the university, or between undergraduate and postgraduate education, than in the social sciences. In contrast, in the social sciences more former doctoral students move to another country after their PhD than in engineering. The target regions differ also: whereas around 85% of former engineering doctoral students stay in EU countries, this share is only 76% in the social sciences. Graduates in the latter domain moved to other continents more frequently, in particular to the US and Latin America, as well as to Asia.

Virtually no PhD students come from North America to any of the included countries and disciplines. Overall less than 1% of the PhD students in social sciences and engineering in the 10 countries were born in North America. The outflow of former doctoral students to North American countries – of course in particular the US – is larger, namely 8% in the social sciences and 5% in engineering. There is some migration from North America to Europe; in particular, re-migration, as 3% of the European post-docs obtained their PhD in North America compared to only 1.5% who were born there.
**Mobility into permanent employment**

The RESCAR study in this area shows a positive picture of employment for PhDs and post-docs in social science and engineering with a large majority of them finding permanent employment immediately after leaving a research field. PhD students leaving for the private sector are more likely to find permanent employment compared to those staying in the public sector. Doctoral students who stay in their country of origin to obtain their doctoral degree are more likely to obtain permanent employment soon after qualifying. Moreover, those remaining in the country in which they qualified have a slightly better chance of obtaining permanent employment soon after. However, recent PhD graduates who opt to take up further research have more difficulty in finding permanent employment posts than those who do something other than research. The private sector is more likely than the public sector to offer permanent positions to post-docs, particularly to engineers, but the advantages vary between countries (for example, the situation in Germany is almost opposite to that in the UK). Former post-docs remaining in or moving back to their region of origin are more likely to find permanent employment there than if they seek employment in a new country where they are migrants. Post-docs coming from outside Europe and seeking employment in the EU countries seem to have a particularly high rate of temporary employment. Post-docs in social science seem to find permanent positions faster than engineering post-docs, contrary to the picture for PhDs. Post-docs from Germany, Spain and the UK get permanent posts faster, whereas French, Italian and Portuguese post-docs take longer to get permanent posts, with a high rate of Portuguese post-docs having to wait a year or more (Robinson et al., 2007, pp.77-78).

<table>
<thead>
<tr>
<th>Mode of international activity</th>
<th>Indicators scope, scale*</th>
<th>Indicator effects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mobility of researchers: outward</strong></td>
<td>Stock / Share of researchers or highly skilled workers (of a country, region, company, institution) having been abroad in the past Stock / share of students enrolled outside their home country Flow of students, PhD, post docs, time series, differentiated for destinations, fields of expertise etc.</td>
<td>Studies on economic gain/loss trough brain gain/drain, no clearly defined indicators Citation analysis (of mobile vs. non mobile researchers) differentiating for the home country and country of resident Career analysis (CV analysis)</td>
</tr>
<tr>
<td><strong>Mobility of researchers inward</strong></td>
<td>Stock / Share of researchers or highly skilled workers (of a country, region, company, institution) from abroad Stock / share of foreign students enrolled in the country Flow of students, PhD, post docs into the country (time series, differentiated for destinations, fields of expertise etc.)</td>
<td>As above</td>
</tr>
</tbody>
</table>

* Potentially those actors are differentiated as for frequency, purpose and duration of stays abroad, as well as for the qualification and career stage of the mobile researchers.
2.2 Industrial R&D

The internationalisation of industrial R&D has been extensively explored over the last 20 years or so. The OECD has recently compiled a concise update of developments (OECD 2008a). As this not the main focus of this study, we limit our discussion to summarise the major indicators, motivations and developments very briefly.

2.2.1 Indicators

The indicators used to measure and analyse the internationalisation of industrial research can be grouped along the meanwhile classical three dimensions of FDI for R&D, international cooperation (of various sorts) and exploitation of technology (Archibugi and Michi 1995). Following indicators are mainly used for those three dimensions (Pilat 2008, OECD 2008, Edler 2008, Rama 2008, UNCTAD 2005, Edler et al. 2002)

1. International exploitation of innovations generated within national borders, for example through technology exports via licensing and/or trade of international property rights so that a foreign organisation can develop and/or exploit abroad the innovative output of national R&D systems. Indicators comprise:
   - International licensing (receipts from international licensing, firm level, country level);
   - Market share with innovations abroad.

2. Global generation of innovation, which involves foreign direct investment in R&D by multinational enterprises aimed at producing or acquiring R&D output from locations other than their country of origin (FDI inward / outward involving R&D activities). Indicators comprise:
   - Share of business R&D (share of R&D expenditure) performed by foreign MNEs;
   - Share of affiliates under foreign control in the business sector;
   - Share of R&D of affiliates abroad as percentage of domestic expenditure;
   - Share of patents invented abroad;
   - Number of labs run or established abroad;
   - Number / share of R&D personnel.

3. Global techno-scientific collaborations for the joint cross-country development of new knowledge, products and services (International cooperation / embeddedness). Indicators comprise:
   - Share of companies collaborating with foreign companies and / or public research institutions in terms of R&D and innovation (across border or as part of FDI abroad, in the latter case this is a measure of embeddedness);
   - Number of technological alliances;
   - Participation in international programmes or in foreign programmes.
2.2.2 Developments

The internationalisation of industrial R&D is growing along all three dimensions above. Country level co-patenting analysis by Guellec and van Pottlesbergh de la Poterie (2001) confirms that the internationalisation of the ownership of technology (cases in which co-inventors are from two or more countries or where the owner and inventor of a patent are located in different countries) is increasing, though again with significant country differences in the extent of internationalisation. For instance, the UK scores relatively highly on internationalisation of technology on such measures whilst Japan exhibits very little internationalisation. In general it appears that, as for science, smaller countries exhibit proportionately more internationalisation of technology, on average, than do larger ones. The table below, reproduced from Guellec and van Pottlesbergh de la Poterie (2001) summarises their country findings for OECD countries for their three indicators, SHIA (share of total country patents with a foreign applicant (owner) and domestic inventor); SHAI (share of total country patents with a foreign inventor and domestic applicant); and SHII (share of total country patents with domestic and foreign co-inventors):

<table>
<thead>
<tr>
<th>Country</th>
<th>EPO (%)</th>
<th>USPTO (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SHIA %</td>
<td>SHAI %</td>
</tr>
<tr>
<td>Australia</td>
<td>11.7</td>
<td>5.3</td>
</tr>
<tr>
<td>Austria</td>
<td>18.4</td>
<td>7.8</td>
</tr>
<tr>
<td>Belgium</td>
<td>31.7</td>
<td>11.8</td>
</tr>
<tr>
<td>Canada</td>
<td>24.0</td>
<td>15.3</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>31.2</td>
<td>5.7</td>
</tr>
<tr>
<td>Denmark</td>
<td>10.8</td>
<td>9.3</td>
</tr>
<tr>
<td>Finland</td>
<td>5.2</td>
<td>7.6</td>
</tr>
<tr>
<td>France</td>
<td>8.3</td>
<td>5.3</td>
</tr>
<tr>
<td>Germany</td>
<td>6.3</td>
<td>4.5</td>
</tr>
<tr>
<td>Greece</td>
<td>13.1</td>
<td>4.2</td>
</tr>
<tr>
<td>Hungary</td>
<td>11.7</td>
<td>2.3</td>
</tr>
<tr>
<td>Iceland</td>
<td>92.3</td>
<td>16.7</td>
</tr>
<tr>
<td>Ireland</td>
<td>26.5</td>
<td>37.2</td>
</tr>
<tr>
<td>Italy</td>
<td>9.4</td>
<td>2.3</td>
</tr>
<tr>
<td>Japan</td>
<td>2.6</td>
<td>1.5</td>
</tr>
<tr>
<td>Korea</td>
<td>4.5</td>
<td>3.4</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>42.7</td>
<td>80.3</td>
</tr>
<tr>
<td>Mexico</td>
<td>48.1</td>
<td>9.2</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>12.2</td>
<td>30.9</td>
</tr>
<tr>
<td>New Zealand</td>
<td>18.1</td>
<td>8.8</td>
</tr>
<tr>
<td>Norway</td>
<td>12.6</td>
<td>14.2</td>
</tr>
<tr>
<td>Poland</td>
<td>35.5</td>
<td>7.8</td>
</tr>
<tr>
<td>Portugal</td>
<td>18.5</td>
<td>10.3</td>
</tr>
<tr>
<td>Spain</td>
<td>15.6</td>
<td>4.4</td>
</tr>
<tr>
<td>Sweden</td>
<td>8.4</td>
<td>9.4</td>
</tr>
<tr>
<td>Switzerland</td>
<td>12.4</td>
<td>26.9</td>
</tr>
<tr>
<td>Turkey</td>
<td>61.5</td>
<td>27.8</td>
</tr>
<tr>
<td>UK</td>
<td>20.0</td>
<td>10.7</td>
</tr>
<tr>
<td>US</td>
<td>5.0</td>
<td>8.7</td>
</tr>
<tr>
<td>European Union</td>
<td>6.5</td>
<td>3.7</td>
</tr>
<tr>
<td>OECD</td>
<td>11.7</td>
<td>11.7</td>
</tr>
</tbody>
</table>

Source: Guellec and van Pottlesbergh de la Poterie (2001)
Turning to OECD data, Figure 2 below confirms that the international exploitation of high technology is growing faster than international trade in general.

Figure 2: Annual Growth Rate of Hi-Tech Exports 1994-2004

Source: OECD 2005

Figure 3 shows the share of industrial R&D that is invested cross borders, both inward (rows) and outward (columns). It indicates the differences in country levels, and the high importance of the US as country of destination.

Figure 3: Share of R&D expenditures of foreign affiliates abroad
By country of destination, 2003

<table>
<thead>
<tr>
<th>Country of destination</th>
<th>United States</th>
<th>Japan</th>
<th>Germany</th>
<th>France</th>
<th>United Kingdom</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>18%</td>
<td>5%</td>
<td>4%</td>
<td>3%</td>
<td>18%</td>
</tr>
<tr>
<td>France</td>
<td>8%</td>
<td>4%</td>
<td>3%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>5%</td>
<td>4%</td>
<td>3%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Italy</td>
<td>3%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Belgium</td>
<td>3%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>3%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Germany</td>
<td>3%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Sweden</td>
<td>3%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Other</td>
<td>33%</td>
<td>10%</td>
<td>2%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Source: OECD 2008, p. 25 (OECD AFA Database)

Figure 4 highlights the heterogeneity when it comes to the relative importance of foreign affiliates in a country.
Finally, in terms of international cooperation for innovation, Figure 5 shows that European firms cooperate intensively internationally, with a focus for European partners.

**2.2.3 Motivations / drivers**

The motivations of firms to internationalise have been analysed in detail by several studies (see Edler 2008, Rama 2008). In principle, the drivers listed above for individual researchers also apply to researchers in companies, albeit within the firm and economic context. Above all, within the very broad and diverse range of reasons, there seems to be a pre-dominant dichotomy of motivations: knowledge exploitation (adaptation) vs. knowledge augmentation (generation) (this goes back to Kuemmerle 1999). Companies need to perform some R&D in foreign markets in order to adapt to local tastes and requirements or they are driven by the search for excellent research conditions, above all critical mass of human resources (for an overview of relevant studies see Rama, 2008).
Interestingly, public subsidies for foreign firms are not a major incentive; it is more about the demand and supply condition in certain countries. Within this dichotomy, it appears that knowledge augmentation, the access to the public research base, the availability of “talent”, the technological and networking capabilities of local companies and institutes and the learning from lead customers is gaining in importance relative to the market adaptation mode (ADL, 2005; Cantwell and Piscitello, 2005; Ambos, 2005; Edler et al., 2002; EIU, 2004; Gulbrandson and Godoe, 2007; Thursby and Thursby, 2006). In a survey by the American Chamber of Commerce, US companies rated the education of the academic staff in a country as the single most important reason for location decision (American Chamber 2005, p. 22).

More recently, the issue of costs in international R&D activities has come to the fore more prominently. For example, Sachwald (2008) has shown that cost-driven R&D is becoming more important and that in addition to the two established business models based on knowledge exploiting or knowledge augmenting, a third business model - striving for more cost-efficiency - is on the rise. This has to do with enabling technologies, advanced organisation to cope with a global division of labour and the increasing availability of low cost but high quality expertise.

2.3 Institutions

2.3.1 International research organisations as a means of institutionalised international cooperation

We begin by considering the set of large scale international research facilities which has grown up over time and which represents a means for international collaboration and an important dimension of national policy when it comes to setting priorities and defining national, internationalisation and cooperation strategies. There are the European collaborative research organisations (often large facilities-based organisations) such as CERN, the European Centre for Nuclear Research (established in 1952 and thus the longest-standing such organisation in Europe) and encompassing enterprises as diverse as the European Space Agency (ESA – established as a single organisation in 1975 to replace separate European space research and launcher development organisations) and the European Southern Observatory (ESO) - which operates ground-based telescopes in the Southern hemisphere (see the useful historical account of Krige, 1997). Krige portrays these developments as driven not simply by the necessity of sharing costs and risks of staying at the leading edge of research but also by a broader European spirit of collaborative institution-building. In particular Krige notes the coincidental timing of early attempts to forge a European co-operation in high-energy physics with Schuman’s proposal of a European Coal and Steel authority. Krige also notes that, whilst such developments had a further driver in the spirit of competition with the United States and other major global players, growing European collaboration in many fields was positively encouraged by the US.

International research organisations can take many forms. As already noted collaborative research facilities such as CERN predominate. There also exist international research-performing organisations (such as the European Molecular Biology Organisation, and the new European Institute of Technology) and a few genuinely international research programmes (such as the Human Frontiers Science Programme). Finally there are also international
research funders such as the European Science Foundation and other international organisations such as NATO are often active in promoting scientific collaboration. Many such international research organisations are formally inter-governmental collaborations established by treaty.

2.3.2 Internationalisation of nationally based research and funding organisations

2.3.2.1 Indicators to measure internationalisation of research institutions

The second dimension within the STI community is the systematic institutional activities of research and funding organisations to foster international co-operation. Increasingly, research organisations and funding institutions (agencies, Research Councils etc.) engage in international activities and internationalisation strategies, either proactively or reactively. Thus, it has become more important to understand also the scale and scope of international activities at institutional level.

A systematic and well established set of indicators to measure the state of international activities and the effectiveness of those activities in research and funding strategies of research and funding organisations does not yet exist. Various studies have looked at the forms and indicators of international research activities at the level of research organisations (Edler 2007, Universities UK 2008, Noir sur Blanc 1999). Potentially useful indicators for the international research orientation of universities are:

- Existence of an internationalisation strategy or plan, with targets, priority areas and priority countries;
- Existence of dedicated budgets and / or a central internationalisation unit to support international research activities (see money);
- Existence of an internationalisation unit to support internally;
- Share of research projects that are done in international cooperation, development over time;
- Number of international partnership or cooperation agreements at institutional level (may or may not be linked to education agreements);
- Share of income for international funding sources.

Some recent development in terms of indicator construction for HEI/ university internationalisation has taken place in the context of the project ‘Classifying European Institutions for Higher Education (CEIHE), led by the Centre for Higher Education Policy Studies at the University of Twente. The latest report from the project describes the development and piloting of a series of indicators for classifying HEIs along a range of dimensions including internationalisation of teaching and research (CEIHE, 2008). The indicators proposed and explored in this study are listed below. In most cases data aggregated data does not exist by institution and the CEIHE project has also piloted the collection of these data from individual institutions:

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10 We do not cover teaching in this study.
11 For details on the project see: http://www.cheps.org/ceihe
• Number of degree seeking students with a foreign qualifying diploma as a share of total student enrolment;
• Number of incoming students in international exchange programmes as a share of total student enrolment;
• Number of outgoing students in international exchange programmes;
• Number of international staff members as a share of total staff members;
• Number of students in joint degree programmes (with an overseas HEI) as a share of total student enrolment;
• The institution’s financial income from EU/international research programmes as a share of total research income.

2.3.2.2 Motivation and Developments
Recent systematic data for internationalisation on the level of research institutes and Universities exists for Germany (Edler et al. 2007) and the UK (University UK 2008). For a stratified sample of 160 HEIs (67 responses) intended to be broadly representative of the diversity of HEI in Europe some additional data has been collected under the CEIHE pilot study described above. The results show a mixed picture (for instance at the bachelor degree level 75% of the responding 67 institutions reported less than 5% international students whilst the percentage of exchange students is also below 5% for the majority of responding institutions, though 20% of responding institutions scored substantially higher on this indicator. Surprisingly, fully one-third of the responding institutions did not report any international staff, perhaps indicating a data collection or research design problem. Finally 40% of responding institutions reported no research income from EU sources whilst another 40% received 0-10% of their income from EU sources and only 10% received more than 25% of their research income from EU sources. It should be remembered that this was an experimental pilot survey and the representativeness of the sample is open to debate. In terms of institutional strategies, the internationalisation of research is increasingly a formal consideration (University UK 2008, Edler 2007, Noir sur Blanc 1999) with almost 95% of institutions responding to a UK survey reporting internationalisation as a key priority.

For Germany, taking all research establishments (including universities) into account, there seem to be two important classes of motive. The first is to access and utilize excellent and complementary knowledge. The second is to secure funding (mainly from EU sources), followed by built up of reputation and visibility of the organisation. There is surprisingly little difference between basic and applied research institutes when it comes to their motives. The German research establishments apparently have no broad strategies to recruit foreign staff. Cost advantages thanks to cooperation with foreign partners do not, as yet, play any role. This contrasts starkly with current strategies in the industrial sector, where firms have increasingly discovered cost-based reasons to relocate research or engage in research co-operations abroad (Sachwald 2008). Lastly, it appears that for a large proportion of the application-oriented institutes, reaching out to foreign firms and keeping step with German firms abroad are important motives. After all, supporting German companies abroad is important for a third of the application-oriented institutes.
3. Political efforts to internationalise STI (5)

3.1 Typologies and Motivations for policy internationalisation strategies

When discussing strategies, policies and programmes concerning internationalisation of research, we need a simple framework to categorise and make sense of them. A first dimension of such a typology is the purpose of the international activity of scientists and firms as outlined earlier. Discussion and developing policies to improve international activities and their efficiency must start with these considerations of the different purposes. A very simple taxonomy from the recent EU expert group on international cooperation in science and technology (2008, pp 25-30) comprises:

- Economic competitiveness, which — though not explicit in the report — one might further differentiate between;
- Being more effective and efficient in generating and transferring knowledge in a certain field (science driven);
- Contributing indirectly to the attractiveness and innovation dynamics of a country / Europe;
- Responding to global challenges, which in effect means contribution to solving a certain problem (problem driven) and also capacity building abroad (development policy through S&T);
- Promoting political cooperation, dialogue and trust, which one might expand, more generally, to fostering other political and societal goals through international R&D activities (these are discussed briefly below);
- Meeting the demographic and educational challenge of human resources for science, technology and innovation (talent seeking, brain circulation, securing adequate supply of manpower for S&T).

The authors further stress that different scientific areas have very different needs for international collaboration (EU Expert Group 2008, p. 30-34)

Further we can distinguish policies in terms of the direction of knowledge flow (Boekholt/Edler 2003). Thus there are policies:

- To attract foreign scientists (and firms active in research);
- To better absorb knowledge that is created abroad (which includes monitoring, the contribution to international scientific activity);

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12 This part is from Edler et al 2008, to be shortened and updated
• To support scientists in their activities abroad (including international facilities) and in their international collaboration and networking efforts and taking advantage of international facilities (support of domestic scientists abroad).

While these types above are of a first order, i.e. they concern the direct effect for science or the economy, some additional cross-cutting aspects are more policy or even politically driven. These include programmes driven by diplomatic and foreign policy considerations, international activities driven by the motivation to influence standards, or indeed activities to show presence. However, all of these considerations will most likely be linked to the first order types above, rather than be complete substitutes for them.

Before outlining the trends of internationalisation of S&T policy in a more narrow understanding, we briefly comment on those more politically driven aspects.

3.2 Political dimensions of international S&T policies

International relations

Skolnikoff (1993, 2001) discusses the role of science and technology as drivers and mediators of international relations. He begins by noting the paucity of studies exploring the impact of S&T on the evolution of international relations and that remark remains true today with one key exception: the significant literature on international (cross-border or global) environmental problems (e.g. Haas, 1992).

Skolnikoff identifies a number of dimensions of the relationship between S&T and international relations:

1. Changing economic relations between nations caused by the evolution of scientific knowledge and technology (replacement of comparative advantage by competitive advantage);
2. Greater economic integration driven by technological change, the development of MNCs/TNCs and the development of high-technology trade;
3. National security concerns around the flows of certain kinds of scientific knowledge and technological artefacts and know-how;
4. The emergence of global problems (or ‘dangers’), especially environmental ones.

International organisations as a means to foster R&D policies and institutions

In a different vein, Finnemore (1993) highlights the role of international organisations in diffusing policy instruments and norms by exploring the impacts of UNESCO on the emergence of science policy bureaucracies around the world, arguing that UNESCO has transmitted the norm of ‘state responsibility for science’ and some institutional arrangements for the organisation of domestic research. The OECD and EU today continue to play an important role in transmitting policy ideas and instruments and facilitating policy learning amongst their members.

Development policy

We have already noted the challenges faced by less developed country scientists in breaking into the emerging global science system. Language barriers apart, problems faced by less developed country researchers include mismatches between an orientation towards applied
research of relevance to the country and the emphasis of the international journals on ‘leading-edge’ basic research excellence and the growing challenges faced by less developed country journals in getting into indices such as the SCI (Gibbs, 1995).

3.3 Trends of international public policy activities

Internationalisation of the STI community has become a major issue for national RTDI policies. In an editorial in Research Fortnight (2007) drawing upon joint work by Evidence and the think-tank Demos for the UK Government (Evidence/Demos, 2007), Jonathan Adams stresses the key policy challenge the UK (and by implication other EU member states) face from a changing ‘geography of research capacity and competency across the world’. For Adams this, more than any other driver, should encourage national governments to audit their existence patterns of scientific co-operation to ensure that those patterns reflect the diverse policy goals of that member state. This chapter summarises some trends in public policy strategy and programming as regards internationalisation of science systems. It is mainly a bullet point summary of the major findings of the recent CREST working group that have been summarised in a 170 pages report (CREST 2007) and of a study on international activities within national programmes (Optimat / VDI 2005). However, we also briefly review the development of policy concerns with researcher mobility, drawing upon Edler/Fier/Grimpe 2008 and RINDICATE, 2008.

In the 1990s, the issue of economic consequences of researcher and highly skilled worker mobility came back on the agenda within the OECD (Salt, 1997; OECD, 2002a). For many years, the major perspective for international mobility of scientists and highly skilled workers has been the so-called ‘brain drain’ discussion, originating in the development discourse (Adams, 1968; Mountford, 1997; for an overview see Nguyen, 2006). Interestingly, whilst the brain drain debate has mainly been focused on impacts upon less developed countries, the first discussions about the impacts of brain drains emerged in the United Kingdom in the 1950s and 1960s in the face of the loss of highly skilled workers and scientists to the US (Cervantes and Guellec, 2002). Thus, the effects of brain drain, gain or circulation have meanwhile been subject to an intensive debate, both in the literature and in policy making, with attempts to leave the focus on negative home country effects (e.g. OECD, 2002b, 2007; Regets, 2007). For example, the UK and the US have intensified their efforts to re-attract or retain scientific elites at the end of the 1990s and beginning of 2000s (Cervantes and Guellec, 2002). For the European Union, in terms of human resources, the European Commission has estimated that in order to meet the 3% objective, a further 600,000 to 700,000 researchers will be needed. This would mean increasing the current level of researchers from 6 per 1000 labour force to 8 per 1000 (COM, 2004). A more flexible and transparent European labour

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13 In a similar vein writing for a US audience De Angelis (2006) warns that the State Department and Office of Science and Technology Policy have woefully underinvested resources and attention towards improving scientific co-operation with China. Meanwhile at the level of individual scientists concerns about the compatibility of Western and Chinese scientific competencies and interests, and worries about scientific fraud and plagiarism, felt by many scientists to be rife in China (see e.g. the editorial in The New Atlantis, “China’s phoney science” in Summer 2006), as well as security, visa and technology transfer restrictions and the usual language and cultural barriers may continue to act as a barrier to collaboration.

14 The CREST report is a very valuable source of information. However, on its basis it is hard to judge the content, seriousness and meaning of all those measures and strategies that are reported, and it is not fully clear how different categories of activities in detail look like and differ between the countries.
Drivers of policies for STI collaboration and indicators

The market for researchers is now viewed as highly desirable for research, innovation and growth in general and for improving employment and working conditions for researchers (COM, 2007a). In particular enhancing the mobility of researchers has thus become an important goal of European research policy (COM, 2000; Casey et al, 2001; Van de Sande et al., 2005). This policy approach is underpinned by the assumption that geographical mobility tends to lead to productive combination(s) of localised knowledge, efficient intellectual exchange to foster international research collaboration and dissemination of good practice and research excellence.

The attempt to promote researcher mobility has to be seen against the fact that researcher mobility is to a large extent of a short-term and temporary nature, as PhD students and Post-Docs gain experience in other developed countries to come back and exploit this in their home country careers. European governments have long been worried about brain drains to the United States but that data which does exist suggests that the long-term losses (as opposed to short-term circulation) are fairly limited (Robinson et al., 2007; Cervantes and Guellec, 2002). As already noted the concept of brain circulation signals the potential gains from temporary mobility in terms of building linkages between source and destination research and innovation systems. European countries have intensified efforts to govern brain circulation (e.g., through an intensified effort within the Research Framework Programmes 6 and 7 of the EU) in order to increase the benefit for European countries (e.g., Thorn and Holm-Nielsen, 2006). The major rationale behind such circulation programmes, it seems, is that gaining knowledge abroad and becoming part of global networks enhances the effectiveness of researchers and thus her or his contribution to science and knowledge transfer into the home country. There is a tacit assumption that more mobility will more or less automatically translate into higher macro-economic benefit. This assumption has led to a “mobility strategy for the European Research Area (ERA)” with mobility seen as a major pillar for the creation of a single European market in science and for the Lisbon Strategy in the area of science and technology (for a summary see COM, 2005). However, if a European research system is truly emerging then a number of potentially serious deficiencies have been identified by scholars, including: relatively poor employment conditions including precarious employment; narrow career prospects; and mobility opportunities hampered by structural, institutional and national boundaries. The Kok Report (EC, 2004a), in reviewing progress in accordance with the Lisbon agenda, particularly stressed the need for Europe to rapidly improve its attractiveness to researchers by reducing administrative obstacles to mobility in the areas of social security entitlements, fast-track work permit and visa procedures and recognition of qualifications. A great deal of recent EC effort has been focused on how to remedy these deficiencies and make a career in research more attractive to the best researchers, to incentivise researchers to stay in Europe whilst also attracting the best researchers in the global marketplace to come to Europe. Despite these efforts the Green Paper on the Future on the European Research Area (COM, 2007a) acknowledges that mobility measures have not proceeded as fast as expected, partly because of limited Community competences in policy areas such as social security, and partly due to a lack of political willingness within Member States to accept Community measures for specific categories of workers.
3.3.1.1 Motivations / Drivers

Motivations for international mobility of researchers are manifold. They differ somehow from motivations on collaborations as they are more geared towards career development or personal/family factors, and therefore less completely driven by individual research aims and content. An empirical study for the German research landscape can illustrate this. In that study, mobile researchers have been asked for their motivations to go and work abroad (Ebersberger et al, 2007). The following picture emerges: the single most important reason for mobility is to improve one’s scientific career, with mobility being positively associated with status and competence. Researchers are also mobile for reasons to do with their own research agenda and in the hope of improving their publication record. However researchers sometimes also go abroad because they find better framework conditions for their work (less bureaucracy, better equipment, more freedom, less hierarchy etc.). The RINDICATE study (RINDICATE, 2008) presents quantitative and qualitative data from a survey of researchers and from interviews with research managers about their mobility experiences and the difficulties they have encountered. In particular it explores the perspectives of researchers who would like to be mobile but who perceive a range of potential barriers to mobility. The study confirms a positive view from respondents towards mobility – as many as 82% of the respondents have either been a mobile researcher in the past or would like to be one in the future. In particular a large group of respondent researchers (35 per cent overall – higher among those under 24 (60%) 25-30 age group (40+ %), 31-40 age group (45%)) were willing to become mobile in the future. However, mobility flows are complex and several factors seem to inhibit or motivate mobility at different stages of research careers. Some inhibiting factors could be addressed with a better coordination of policies between Member States. Others represent more serious challenges, such as child care and personal relationships. The latter are likely to be more difficult, or more costly, to address with policy measures than are other barriers. The findings of the study confirm that there are both push and pull forces affecting mobility of researchers and that these have asymmetric consequences both for receiving and sending research institutions and for the professional and personal lives of individual researchers. What may be an inhibiting factor for the career development of a researcher can also become a push factor for mobility. In short mobility is a dynamic process lived out through the life-course of the individual researcher and will have ‘positive’ and ‘negative’ knowledge, capacity and personal effects at different times and places. Assessing the risks, costs and benefits from mobility, and determining desirable levels of mobility depends entirely on perspective and timeframe. In particular it should be remembered that push and pull factors and barriers may vary over time, from discipline to discipline, and between different kinds of research-performing institution and research system.

Broader strategies, concerns and policy action – the CREST working group report

Out of 22 countries reporting on internationalisation strategies within the CREST study, 10 claimed to have a comprehensive strategy in place, three of which as part of a general globalisation strategy (DK, RO, BE), 7 as part of their S&T strategies. Apparently 8 countries are in the process of defining a strategy. From our own findings in the interviews, the impression is confirmed that there is an enormous interest in strategy building, but at the same
Drivers of policies for STI collaboration and indicators

Time strategies do not appear to be operative and are not used to guide the actions of policy makers. While there are new discourse structures and explicit strategies in place and many, also novel, important activities stem from strategic considerations, overall coordination, goal setting, visions, road maps and re-adjustment of action lines are still the exception rather than the rule (e.g. our cases of Finland and the UK who both claim to have an internationalisation strategy). Strategy development and, in particular, implementation remains more of a promise than a reality in most of the countries (CREST 2007, p. 12-14).

The drivers for internationalisation strategies are very similar across the countries reviewed, and there appears to be a canon of drivers widely shared within the European countries (CREST 2007, II-III): In general, the most important drivers are: (1) strengthening (domestic) excellence through access to existing excellence and facilities abroad, to increase the attractiveness of domestic systems (inward mobility), (2) preparing the ground for domestic innovations to be marketed abroad, and (3) to contribute to the solution of global problems.

However, the countries recognise that there are pitfalls in engaging in international activities, such as IPR issues, brain drain (instead of brain gain or circulation), the relocation of key companies or scientists to other countries and regions. Thus, strategies need to be developed that ensure the embedding of companies and research organisations in the domestic system, to broaden the impact of international activities for the system as such, to stress brain-circulation concepts, or to monitor and make accessible the knowledge abroad for domestic actors.

The CREST group concludes that to overcome the obstacles standing in the way of a broader internationalisation concept, discourse within the government and with all kinds of stakeholder must be intensified and existing policy mix and framework conditions must be re-examined in light of international challenges and opportunities.

Priority setting within internationalisation strategies in terms of countries and fields has been classified along six rationales. These are, to some extent, mirrored in the more or less explicit prioritisation activities in our country cases (below): (1) expected scientific benefits, (2) political / diplomatic reasons, (3) market access, (4) mobility gains, (5) reputation / promotional aspects, (6) specific geographical, historic, linguistic and cultural ties (CREST 2007, IV-V). It must be stressed that although each of these reasons has its justification, our country cases reveal that they are often not compatible and a major source of frustration in international science policy making stems from a lack of coordination between the different responsible ministries or agencies. The CREST report claims that a new trend towards better coordination between ministries is visible, especially when it comes to specific issue areas such as water, energy, etc. However, experience within this study team, in many countries and on European level for many years, indicates that given the widespread distribution of responsibility for science and innovation, true coordination remains elusive.

Further, the CREST report shows that the thematic priorities are either not set explicitly, or only set \textit{ex post}, i.e. after country targets or modes of activity have been decided upon. In other words, there are not many strategies for certain scientific disciplines or issue areas, rather, strategies are about overall goals, horizontal activities and country foci.

The lack of comprehensive, recursive strategy development is also apparent in the data given by the countries on evaluation and monitoring. Formal evaluation of publicly supported international cooperation activities seems very much to be the exception rather than the rule. The main exceptions here are participation in the Framework Programme and European programmes such as COST and EUREKA and a limited set of multi-lateral programmes such as the Human Frontier Science Programme. This may be an indicator that internationalisation,
while being a policy concern for many years, has only recently come to the full
attention of strategic policy makers as a dimension of S&T policy making that cuts
across most activities and must be exploited much more strategically
(internationalisation as an “emerging pillar” CREST 2007, p. VII).

Possibly the major area of concern – and increasing activity – for policy makers is
mobility of researchers. There seems to be a development from avoiding brain drain to
establishing brain circulation. This reflects the increasingly widely-held belief that the
benefits of mobility come not only from attracting foreign researchers into the
domestic system, but also from exposing domestic researchers to overseas science
systems for a time.

In terms of attracting foreign companies (rather than individual researchers), there
has been a shift in emphasis in recent years towards not only attracting them, but
actively embedding them into regional or national systems so as to maximise the
possibility of spillover effects. One example for this is the Austrian Headquarter
Strategy Programme, which seeks to link specific incentives to attract leading R&D
labs of multi-national firms with the provision that they engage in domestic
cooperation, with other firms and with public research. However, while these intentions
are genuine, policies to embed companies, even with financial incentives, are
extremely challenging, and from all the anecdotal and academic evidence it seems
clear that those systems that are strong in scientific and / or technological terms, that
have built up networking traditions and accessible public research organisations and
that do not discriminate negatively against foreign actors are best equipped to make
foreign industrial R&D activities spillover and ‘stick to’ the country (see Edler, J. et al.
2006).

*International activities in national programmes*

Unusually, the CREST report does not discuss the openness of national programmes,
although this is one of the most obvious means of seeking to increase international
activity (cooperation and inward mobility) without requiring a trade off against
existing programme goals. We can speculate that one reason for this might be
functional specialisation in the member states, whereby international activities, as a
horizontal consideration, are not fully backed or even coordinated by vertical thematic
programme owners. Whilst there is enthusiasm to take advantage of international
opportunities in specialised units of ministries, the thematic programmes may be
more introspective and perceive the international dimension as a threat to their remit
or control. The figure below depicts the results of a survey done for the European
Commission, which asked national programme owners about these various models
within their programmes. One has to keep in mind, however, that the share of the
budgets that are spent on international activities within national programmes remains
below 5% (Optimat/VDI 2005), i.e. while programmes may be open in principle, the
investment in international activities is still very low. The CREST report does not,
interestingly, systematically discuss the rationales and activities vis-à-vis international
large scale facilities and European infrastructures. In this regard, the countries show
more awareness of the importance to be engaged in these organisations through
national personnel.
Figure 6: Relative prevalence of modes of international activities in national programmes


Halme et al (2004) explored the impacts upon the internationalisation of Finnish RTDI of 64 Technology Programmes, one of the key instruments of the Finnish agency Tekes. In a small comparative review of six mainly small European countries\(^{15}\) they found that little national policy effort was directed at outward technology links of domestic firms in comparison with the effort directed at attracting inward investment and mobility. The findings on the Finnish programmes suggest that whilst most of the programmes had international dimensions of some kind (ranging from the inclusion of joint research projects to the invitation of international experts as speakers or consultants) it was relatively difficult for the programmes to encourage internationalisation at the level of the content of individual projects. Some evidence was collected that universities and research institutes were more ready and willing to internationalise than were companies, suggesting that universities and institutes could potentially play an important role in linking national research and innovation systems.

3.4 Indicators to map internationalisation policies and their success

The development of indicators of internationalisation policies or individual instruments is at its earliest stage. This reflects the fact that, as can be seen in the country review of this study, countries are just beginning to systematically design and review their internationalisation strategies. The process of reflecting on the status quo of international STI cooperation and engagement that is at the start of those strategies and the search for quantitative and qualitative has triggered off a search for indicators. However, this is not reflected in the

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\(^{15}\) Sweden, Germany, Switzerland, Ireland, the Netherlands and Estonia.
broader literature on STI policy or STI evaluation yet. For example, the most comprehensive compilation of evaluation methods and indicators to be used in Europe, the European RTD evaluation toolbox (Fahrenkrog 2002), does not discuss specific indicators and methods to be used for international activities. The same is true for a similar toolbox developed in the US ATP programme (Ruegg/Feller 2003). The international dimension of evaluation and measurement of success mainly comes in when countries attempt to assess their relative performance against other countries (Georghiou/ Larédó 2006, p. 35).

The simple conclusion here is that, in the absence of specific internationalisation indicators, assessments apply well-established evaluation tools and indicators against the specific set of goals of international programmes and against the specific cost-benefit ratio of those programmes. In the absence of well established specific indicator schemes for policy activities geared towards international activities in the evaluation literature, this appears to be a second best and pragmatic option as shared in the evaluation literature: to define and operationalise the direct (e.g. project result and output) and indirect benefits (such as learning, new access to expertise and infrastructure, strategic opening to global partners in the future, unique contribution of foreign partner and so on) and to weigh those against the additional costs through international activity (transaction costs, potential efficiency loss etc.).

While the main part of this study reports on the current efforts to develop specific indicators, here we briefly summarise some attempts to be found in conceptual and empirical studies of internationalisation programmes. In light of the growing importance of policies to promote and support the internationalisation of research, this kind of analysis will become increasingly important for the design and re-design of supporting policies, and is thus at the heart of our study.

The indicators to be found in the literature are mainly at the level of individual activities or policy interventions rather than at the level of internationalisation policies. An overall assessment of the ‘state of the art’ of internationalisation policies and the overall impact of those policies is still missing.

Making sense of the benefit of international activities and their national policy support

To support US policy development on internationalisation activities in STI, Wagner (1997) has developed a framework for measuring and assessing international STI co-operations (see Table 5, below). To reduce complexity, she has defined four types of international co-operations based on principal motivations. These four types do not capture some of the motivations we have defined above. However, though limited, they still capture the mission orientation of international STI cooperation and therefore the link to goals beyond STI itself. The approach illustrates how benefit can be made explicit and, subsequently, impact indicators or measures can be defined. The value of the approach is twofold:

1. The framework shows the importance of understanding the drivers for international cooperation in order to measure their benefits. It entails four categories of cooperation drivers. Most importantly, beyond three sets of drivers that are intrinsic to STI, the fourth category captures the instrumental nature of international STI activity, whereby the activity is undertaken to serve some government mission and thus political or societal goal;
2. The framework distinguishes between different kinds of support for international activities. This support is divided into three different kinds: support for research collaboration, technical support, operational support and database support. Table 4 below shows what kinds of benefits are to be expected in all the four categories and how those benefits could be measured.

A second illustrative example is the assessment of the internationalisation dimension in national technology programmes of Finland, as discussed above (Halme et al, 2004). The review suggests that elaborating the internationalisation aims of national technology programmes into a clear strategy is essential if such programmes are expected to serve this policy goal. They go on to propose four approaches to the design, implementation and follow-up of programmes according to the broad type of internationalisation goal they are expected to support (big science goals; upgrading Finnish competence with international knowledge; exploiting Finnish competence abroad; and other policy goals). The approach is reproduced in summary form in Table 4 below:

Table 4: Approaches to the design, implementation and follow-up of programmes

<table>
<thead>
<tr>
<th></th>
<th>Big Science programmes</th>
<th>Up-grading Finish competence</th>
<th>Exploiting Finish competence</th>
<th>Regulatory &amp; other changes as drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design and definition</strong></td>
<td>Selective participation with ambitious objectives.</td>
<td>Preparatory studies on up-grading needs and available technological expertise abroad. Internationalisation plan, with specific objectives and synthesis of domestic dissemination.</td>
<td>Preparatory studies on market needs and structures abroad. Key market / application oriented internationalisation plan. Collaborative design with other service providers.</td>
<td>Preparatory studies on policy and regulatory developments. Preparatory studies on similar programmes and developments abroad – possible joint actions.</td>
</tr>
<tr>
<td><strong>Follow-up</strong></td>
<td>Ensure a seamless follow-up usually with a new programme.</td>
<td>Follow up with other programmes or specific follow-up instruments.</td>
<td>Technology programme as a catalyst – follow-up with other business oriented/innovation instruments.</td>
<td>Follow-up with specifically targeted programmes or specific follow-up instruments.</td>
</tr>
</tbody>
</table>

Table 5: Benefits and Measurement of international collaboration and supportive activity

<table>
<thead>
<tr>
<th>Reasons for Cooperation</th>
<th>Collaborative Research</th>
<th>Technical Support</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Expected Benefits</td>
<td>Suggested Measures</td>
</tr>
<tr>
<td>Very large scale equipment</td>
<td>Enable conduct of large-scale project beyond reach of any one country; gain access to foreign equipment; lower cost of research (e.g., space station; ITER; EPR)</td>
<td>Agency report on meeting milestones; survey participants for foreign $ and/or in-kind contribution; expert judgment of technical feasibility/excellence; survey records; U.S. percentage of time accessing equipment</td>
</tr>
<tr>
<td>Global nature of subject</td>
<td>Access to subject of study; leverage scarce funds; improve environment or reduce hazards (e.g., CCG; Ocean drilling, earthquake research)</td>
<td>Survey scientists: gaining access to subject/data. Survey agencies/investigators: leveraging foreign funds. Citation search: no. of co-authored papers increasing. U.S. report: reducing specific hazards in U.S. (the rest of the world)</td>
</tr>
<tr>
<td>Unique foreign expertise</td>
<td>Enable excellent science; share data; improve productivity of research; improve U.S. science base (e.g., French excellence in materials science)</td>
<td>Citation counts of jointly published articles compared with nat'l counts; tabloid counts of increased improve productivity of unit of knowledge produced; joint patent counts</td>
</tr>
<tr>
<td>Government/agency mission</td>
<td>Either meet direct need of agency for new knowledge (e.g., energy) or improve foreign security or living conditions (e.g., DOE's energy security; AID/UN's aid for infectious disease control)</td>
<td>Use bibliographic counts to show access to best knowledge in world; expert judgment or reduced risk; U.S./other int'l org indicators of improved living conditions</td>
</tr>
</tbody>
</table>

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*Originally, Conseil Européen pour la Recherche Nucléaire. Now known as the European Laboratory for Particle Physics.*

*CEC (Commissariat à l'Énergie Atomique).*

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Making sense of the benefit of international activities in international organisations and programmes

Besides national programmes and support activities, an assessment of the internationalisation of STI must cover the truly international programmes and organisations. These range from supranational programmes such as the EU Framework Programme\(^{16}\), multilateral programmes such as the Human Frontier Science Programme to dedicated intergovernmental research organisations such as CERN. Again, two illustrations show how the international dimension can be analysed and measured, and can inform the search process for adequate measures of international ST&T collaboration. (This section originated in the context of a conceptual development for the Irish government (Edler et al. 2008), demonstrating the value of understanding benefit of international organisations and facilities when it comes to design internationalisation strategies.)

The first example is the evaluation of the Human Frontier Science Programme (KPMG et al 2001). This programme is offering the opportunity for global cooperation in basic science, is based in Strasbourg and financed by a set of countries. The indicators used to measure its benefit and impact in terms of the international component are\(^{17}\):

- **Opportunities for research** (specific to the international programme)
  - Scope and excellence of the collaboration team (intercontinenitality, scope and quality of participation);
  - The infrastructure offered (through the international pooling);
  - Degree of intellectual challenge (leading edge through international excellence);
  - Interdisciplinarity (better tailored interdisciplinary teams);
  - High risk topics (cost sharing through international pool);

- **Output and impact**
  - High quality outputs measured through bibliometric indicators such as number of top journal articles and relative citation rates (supporting the idea of added excellence through international cooperation);
  - Subsequent international / intercontinental cooperation (indicating the enlarging of geographical scope for cooperation);
  - Impact on subsequent careers (high level networks, visibility, new lines of research).

Second, there are examples of evaluations of national participation in intergovernmental research organisations (Bodenhöfer et al. 2004, Schenk 2007) which serve to assess the net benefit of participation. These kinds of considerations are increasingly important when it comes to establishing and financing joint large scale research organisations and infrastructures on a global scale. Here the overriding question is whether the combined costs

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\(^{16}\) We do not cover the assessment and indicator development around the European Framework Programme here, as we limit ourselves to international rather than intra-European cooperation. The specific methods and approaches used to assess the Framework Programme can best be found in Georghiou et al, 2002 and

\(^{17}\) Programme characteristics such as flexible use of funds and management aspects are not unique to international programmes and need no mention here.
of membership (including opportunity costs) in those joint international organisations are justified through the direct and indirect benefit of participating in projects, of using the equipment and of realising additional economic gains. The following list of indicators is compiled from two studies that cover a broad range of indicators and dimensions (Boenhöfer et al. 2004, Schenk 2007):18

**Thematic match analysis**, mapping a) the **thematic areas** of the organisations to a) the scientific **megatrends** and b) to the **national priorities**, finding a strong position of ESO in this triangular relationship. Further, the share of membership fees out of public R&D spending is compared to other countries.

**Characterisation** of each organisation following **11 descriptive uniform criteria**: breadth of topics covered, basic/application oriented research, theoretical orientation, spin off potential, position of the facility within the scientific discipline in general (leading edge?), integration into the international community (centrality), service character (providing necessary equipment), potential for further training, independence of the research programme, relevance of the results for society.

Aspects covered for cost-benefit assessment:

**Costs**
- Annual fee and one-time start investment;
- Opportunity costs (value of alternative spending of the money);
- Scientific costs of non-membership: costs of alternative infrastructure, access to infrastructure and database for non-members (ESO: exclusion from scientific database for non-members), costs of alternatives, if any are available, consequences for recruiting international stars in the field.

**Benefits**
- The actual usage of the facilities;
- The direct scientific outcome for the Swiss scientific community (publications);
- Broader scientific merit: scientific capacity to profit, fit to national priority, enabling for excellent international collaboration etc.;
- The educational effects for young scientists (learning, exchange), enhancing the attractiveness of the country as scientific location;
- The effects on industry;
  - Expectations of direct and indirect benefit, especially in terms of spill over to complementary technologies, with a listing of potential beneficiaries;
  - Industry Return Coefficient, relating the share of supply to the IGRO by national industry (through procurement) to the share of membership fee the country is paying;
- Governance: the way the scientists are integrated into the governance and decision making in the facility;
- Foreign policy aspects: what signals have been sent in the past, how will a decision be assessed elsewhere, what does hesitation mean in terms of alternative international activities?

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18 This summary description is a modified version of the summary provided in Edler et al. 2008.
**Definition of success factors**

- Human resource: a high concordance with national research priorities, scientific standing of domestic scientists internationally;
- Scientific benefit: high foreign policy relevance, duration of membership (effect takes time);
- Economic benefit: no clear assessment possible.

This overview of indicators actually used to assess the net benefit of participation in International Organisations shows the breadth of criteria to take into account. While these kinds of indicators and assessments are specific to International Research Organisations and large Facilities they nonetheless provide an overview of what might be possible.
4. Summary: changing drivers - need for indicators

This review has summarised the drivers, indicators and developments in international S&T collaboration at four levels: the individual researcher, public research institutions, firms and, last but not least, policy. We have seen that there is a broad array of drivers at the various levels and that the scope of drivers appears to have broadened and certainly has shifted in recent years. For the individual, international cooperation and mobility is becoming almost a condition sine qua non when it comes to academic career and impact. Internationalisation of firms is on the rise, as well, with a shift to knowledge seeking globally and combined with efficiency considerations (costs). Although science has always been highly international, scientific institutions and funding institutions have been latecomers when it comes to institutional internationalisation, but internationalisation strategies are being developed now at all levels, even if especially funding organisations are still struggling with the design and implementation of strategies, the right level and modes of international involvement. Finally, STI policy, as the CREST report has shown, is just at the beginning of a journey towards more conscious and comprehensive internationalisation strategies that link bilateral, European multi-later, European and global approaches and are driven by a broad scope of motivations.

The review has also reported broad attempts to measure the developments and thus to underpin the strategic moves on individual and institutional level. There are indicators for the scale and scope of activities as well as for the impacts. Only a few dimensions of internationalisation are at present well served by existing indicators. In order to better match the broad range of drivers and intentions with evidence, a list of indicator deficiencies can be constructed. We miss sufficient indicators and data to measure:

- International activities of individuals (CV analysis etc., is in its infancy), especially when it comes to mobility;
- The sectoral and technological patterns of industrial cooperation;
- Cooperation in innovation more broadly (one proxy is within CIS19 data only);
- Embedding of overseas actors within the host system;
- The extent to which international collaboration is pushed and financed through global challenge organisations;
- The scope of internationalisation of national policy and programmes (whereby here the bottleneck is not the indicators, but the lack of will to fill them with data).

Above all we miss indicators to measure the effects and impacts of international collaborations of all kinds. Activity and output indicators often exist, and are often key in mapping internationalisation of researchers, institutions and firms. At the policy and funding level data is more patchy and at all levels, even in cases where evaluation and monitoring collects information on international activities, there is no focus on the impacts of such activities, whether positive or negative. Determining the impacts of internationalisation activities presents a significant challenge to evaluation and strategic intelligence more generally and here policy makers will have to work closely with analysts to determine innovative new approaches which can tackle this gap20.

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19 Community Innovation Survey

20 Of course evidence of systematic strategic intelligence collection which influences internationalisation policy decisions and systematic evaluations of internationalisation policies (and not just individual instruments) which take into account their policy goals and which shape policy learning could itself be considered to be an 'indicator' of a sophisticated policy orientation towards STI internationalisation.
Without better evidence in this regard, better data on activity levels will be of limited use. A crucial problem in this regard is the difficulty in distinguishing between drivers of internationalisation which can be considered to be ‘internal’ to the scientific enterprise and ‘external’ pressures\textsuperscript{21}.

\textsuperscript{21} Fuller (2000), discussing the ever-growing capital-intensity and ‘materially interested’ nature of modern science, discounts the idea that these trends are the result of a ‘natural’ internal trajectory of modern science, arguing rather that such developments are constructed over time and then reinterpreted as inevitable by a number of ‘intermediation’ processes which obscure the choices thus made.
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