Ministerial Round Table

Structure, Organization and Funding of Scientific Research: the role of the State

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WORKING DOCUMENT

Policy structures, organizational structures and funding mechanisms for science, technology and innovation; challenges for developing countries

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Countries should commit to invest in research

Experience leaves no doubt that innovation (developing and commercially and/or societally exploiting new products, processes, services, infrastructures, etc) is vital for the success of companies (i.e. at the *micro-economic* level) and economies (the *macro-economic* level), as well as to increase individual freedoms, the quality of life and societal well-being (the *social* level).

OECD countries show that higher R&D per employee and more intense technology diffusion correlate strongly with total factor productivity. The impact of innovations in communication, mobility and e.g. health care on the quality of life is unmistakable. Innovation is the result of technological development in combination with organizational changes, new management methods, marketing concepts, financial techniques or policy approaches. All of these increasingly rest on scientific research, in the natural, engineering and medical sciences, and today to a greater degree in social sciences and humanities than in the past. Previous developing countries in East and South-East Asia, in Latin-America and also South-Africa demonstrate that this is the way ahead. Companies do invest in research and development which they wouldn't do if good economic reasons were absent, and that is why in almost all OECD countries business funding R&D has increased considerably. But firms are withdrawing from longer-term research, while patents reveal that they rest increasingly on academic research results (citations in patents of academic publications). So here is an important reason why government investments are necessary to maintain the overall R&D enterprise. More generally, there are three compelling arguments. The first focuses on improving the quality, productivity, cost-effectiveness and accessibility of a variety of services, infrastructures and policies for which the government itself is totally or largely, directly or indirectly responsible. Examples are defense, education, health, water, energy and food security, physical infrastructures, governance, social security, protection from crime, or regional and global obligations governments increasingly engage in (e.g biodiversity or climate change). As an illustration, in agriculture (where government has always played an important role) the dramatic increase in productivity has been largely the consequence of science and technology: feeding one person in 1900 required ½ ha and more than 1 year of labour; that same ½ ha today can feed 10 persons with only 1½ day of labour. Secondly, while basic research is not a pure public good (that is others can use it without diminishing the value for its producers and other firms cannot be stopped to use it), it is obvious that firms will not invest in all the research they will eventually use. Here the governments have to and have always stepped in through the funding of research in universities and institutes of basic science. Thirdly, however, much knowledge is 'tacit' knowledge and embodied in persons, procedures, organizations. Also using published knowledge requires extensive (and expensive) learning processes; capabilities (people, equipment) are necessary to appreciate and assimilate ('absorb') results from elsewhere. This leads to the modern rationale for investment in public (basic) research. Basic research creates technological opportunities; it increases technological diversity by providing a source of new interactions, networks and technological options, whereas firms tend to exploit the variety in an existing technological path; and it is also a source of skills, required to translate knowledge into practice; an enhanced ability to solve complex technological problems; and the 'entry ticket' to the world's stock of knowledge.

Four key areas in the policy, organization and funding systems for science, technology and innovation

Countries that have been able to benefit most from science and technology have built up systematically ways and means to carry out research and development and to support firms, hospitals, government agencies and other organizations in society at large in applying the results of research, whether carried out domestically or abroad. Several common characteristics are to be found and developed countries, emerging economies and some developing countries are not very different in this regard. This working document reviews the main structures that have proved successful, and suggests contrasting commonalities in most developing countries. Key challenges then become obvious. A couple of terminological points need to be made. In the first place scientific and technological knowledge which is the result of research and development covers all fields of sciences: so in this document natural sciences and engineering, mathematics, life and medical sciences and social sciences and humanities are all included. Secondly, there is a distinction between research and development (R&D) and science and technology (S&T). This is most clear when one compares expenditure statistics: expenditure on S&T encompasses all expenditure on R&D but in addition expenditure on so-called S&T services and for example education in S&T. In this document R&D and S&T will be used interchangeably as in the practice of policymaking and organizational and funding mechanisms the differences are not very important: one finds ministers for research and in other countries ministers for science and technology. Innovation, though, must be treated somewhat differently. Innovation is the business of businesses or hospitals or agencies that manufacture products or provide services. Producing these products and providing such services is paid for by customers or by sectoral government budgets, e.g. for public health care. When one speaks of STI (science, technology and innovation) policies as is nowadays common, one has in mind that there is a role for governments to support and promote innovation. But such a responsibility, which resembles in many ways a catalyst, cannot substitute for the primary responsibility of firms (and in the background economic and industrial policies) and of sectoral ministries.
In subsequent sections the focus will be on

- Governance, policy and the legal framework for STI
- 'Performing' R&D: institutions and operating conditions
- Funding R&D and supporting innovation: institutions and instruments
- A crucial enabling factor: Information and Communications infrastructure.

Governance, policy and the legal framework

In many developing countries establishing a national body with responsibility for science and technology was part of the initial institutional framework. Various names occur such as a national council for science and technology or a national or state commission for science and technology. They had and sometimes still

have a series of responsibilities: defining policies for science and technology, coordinating science and technology and funding R&D are often included, but also supervising or managing research institutes. Registration of ongoing research, responsibility for compliance with (international) provisions (biodiversity, ethics for example), and proposing legislation for intellectual property, and occasionally even running a national patent office are to be found as well. Academies of science, especially in countries emerging from the Soviet Union, in many cases had an amalgam of such responsibilities, and some still have.
A key lesson that successful countries have learnt is the need to differentiate several of these functions and to articulate them in separate organizations, some of them within the government structure, some at arms length or completely independent.

A responsibility for setting STI policies at cabinet level
Responsibility for setting policies for STI must rest at cabinet level. If the person who is in charge of the body responsible for STI policies, say a president of a National Council for STI, has no part in cabinet level discussions where decisions on budgets, on national priorities and on key legislation are taken, it will be very difficult to represent adequately the interests of science and technology. Substantial amounts of public money will eventually be involved and one particular difficulty is that these are on average longer-term investments which will not pay off immediately as the construction of a road or a hospital would. One finds various solutions as to how precisely this responsibility can be instituted. A minister for Higher Education and Science and Technology (or Research and Development) is an option adopted by several countries. A secretary of state or deputy-minister with similar responsibilities within a broader ministry of Education is also to be found. A department for Science and Technology is a solution chosen for example by South Africa. Two different options have their own rationale. One is to not combine responsibility for science and technology with higher education (which is natural as universities are usually key players in carrying out research) but rather with responsibility for economic or industrial policy. Yet another is to stress the pervasiveness of science and technology by making a deputy-minister in the prime minster's office responsible for science and technology. In some countries, both developing and developed ones, one finds a separate minister for Information (and Communication) Technologies. Uganda is a recent case in point. That can be a good starting point for identifying a broader responsibility for science and technology. There are pros and cons for each of these solutions, and countries switch over time. The UK for example has in a way over the past decades opted for the 'prime minster's' solution, for the combination with industry and economic policy, and now for the combination with education.

Coordination across government departments
Closely related to setting policy for STI, is coordinating science and technology or research and development. The key point here is that also in developing countries significant amounts of research are the responsibility of sector ministries. Common cases in both developing and developed countries concern ministries for agriculture, forestry and fisheries, the health ministry, the ministry for defense, the energy ministry or the industry ministry (which may involved a national standards agency). There is nothing wrong with these diverse responsibilities. Countries which have considered to centralize responsibility for all research within for example a ministry for research (France had gone some way in this direction) have at the very least established a co-responsibility for key research agencies with the respective sector ministries. In all cases the issue of coordination arises for a variety of reasons. Funding and evaluation mechanisms need not be specific for different sectors; indeed their efficiency en quality can be enhanced considering them from a cross-sectoral perspective. National priorities require also a broader perspective which will include moreover university and other academically-oriented research. Universities are also linked to other parts of the research endeavours in a country through human resources: there can be specific demands for training, which in turn require a broader discussion. National programmes may fruitfully target both researchers in universities and in sector research institutes, and this may of course extend to public-private collaborations as well. Avoiding duplication, and rationalizing the national research effort by occasionally evaluating in which institutional environment particular research activities can best be carried out, are other reasons. As will be discussed in the next section some countries opt for bringing most research in the realm of universities, Denmark being a case in point and Sweden having done this basically for a long time. Again, charging an

outside body such as a national council for science and technology with responsibility for this sort of coordination does not work. The solution one finds in many successful countries consists of some elements. Formally a minister or deputy-minister responsible for science and technology is also made responsible for coordination of all of research. Practically this often means that an interdepartmental committee of high-level civil servants, usually those who bear responsibility for the sector ministries' research efforts, takes care of coordination. They prepare joint programmes, discuss generic legislation applicable to all or many domains, discus national priorities and so on. An important tool in all cases is to have a budgetary overview of all R&D or S&T expenses in a country. That does not imply that there is a single budgetary responsibility for research, but it may serve a useful purpose in annual budget discussions with the minister of Finance or in the cabinet. Coordination, that is looking at the national research effort as a whole and in a broader perspective, is also served by an external advisory council. This was indeed the third element, next to an interdepartmental committee and an annual budgetary overview, that was identified when OECD countries started to work out the institutional set-up for science policy in the 1960s. An advisory council would normally comprise high-level scientists, industrialists and representatives of various societal sectors, but they would act independently and in a personal capacity.

An Innovation Council to commit public and private stakeholders at high level

In several countries a new type of body has emerged over the past decade or so as an expression of the importance science and technology, and education, for the socio-economic development of a country. The increasing focus on innovation as the mechanism through which the impact of science and technology is often realized, and the awareness that an international, global perspective must be developed only add to the reasons to create such a Research and Innovation Council (which is the name of a successful example in Finland). The essence is that government, industry, research organisations, universities and vocational training institutions agree on and commit to a medium- and long-term vision and strategy for economic and social development, and the role of increased competitiveness and innovation. For that the government creates a high-level body combining key stakeholders from the government, the private sector and other institutions. Typically one would find the prime minister as chair, several ministers, key industrialists (including the service industry), educational stakeholders, representatives from the banking sector, but others speaking for the environment or labour may be present as well. Developing and agreeing on key components of a strategy for economic development; committing to work together, to coordinate activities, and to mobilise and commit the members' respective constituencies; defining systematic action plans (for example as regards incentives to improve the business environment and entrepreneurship; human resources development; technology, knowledge and innovation; the information infrastructure; communicating with society at large; and monitoring and measuring progress would be key roles of such a Council. It does not take over formal responsibilities but if stakeholders indeed commit to a direction and to work together it may be a powerful informal instance of coordinating across the public and private sector.

A generic law on STI?

Much emphasis is often put on the legal framework for science and technology policy. A distinction must be made here between a generic legal framework, for example a law on science and technology, and specific laws whether these are 'organic' laws to legally found certain institutions, or laws or regulations governing the activities of researchers or institutions. Many countries do not have a generic law on science and technology. Indeed, if the institutions are in place, responsibilities for science and technology policy have been defined and have a natural place in negotiations on responsibilities at the formation of a new government, and funding for research is explicitly part of the annual allocations of public budgets to specific institutions (universities, a funding agency, research institutes, etc), there is not much to be gained by adopting a generic law on science and technology. When countries make a new beginning, however, by introducing significant changes in the way policy for science and technology is being made, and perhaps all the more when such responsibilities only begin to be discerned, differentiated and articulated, having a generic law may be important, as it were to establish a tradition and to ensure that changes cannot be made too easily to the science and technology framework that by its nature depends very much on a considerable degree of continuity. Such a law would identify the major institutions and responsibilities for policy making and coordination but also create a legal basis for key operational tools such as an annual budgetary overview and for example a national, say, 5-year plan that many countries feel important for presenting priorities, targets and milestones, actors and their key activities, evaluation mechanisms, and so on. It could as well provide the legal basis for institutions that hold key responsibilities in implementing policies and a national plan, if any would exist. An example is a national funding agency for academically-oriented research or an agency tasked with supporting innovation in companies. The most important condition that must be fulfilled when considering introducing such a generic law concerns funding, however. If no regular funding streams are identified, and if in the government budget no provisions are made for making available money for research, much of not most of the impact of the law disappears. In fact, what one does see rather often in developing countries, is an accumulation of formally very useful elements, which have only a very limited effect because each of them presupposes the availability of funding. A National Council for Science and Technology, a National Science Fund, a National Policy for Science and Technology are to no avail if the actual funding is not forthcoming. Considerable efforts of many individuals in and outside the government are usually involved in elaborating all these elements, and at a moment when governments all over the world are stating and restating their commitment to build development and poverty eradication in important ways on science and technology, the main area for action is to make available funding from tax income, and spending those funds through transparent financial mechanisms.

Specific laws are essential

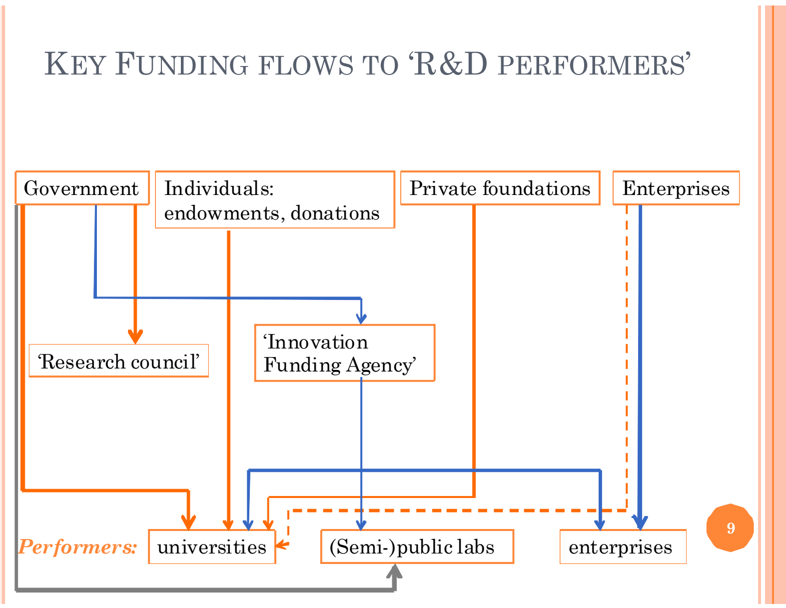
Laws to deal with specific circumstances are crucial for the research enterprise. One instance is the legal framework for intellectual property rights, and the ensuing institutional set-up for implementing such a framework. Regional cooperation can be very useful in this specialized area as the example of the patent office in Harare, Zimbabwe, demonstrates. There is legislation concerning scientific experiments involving human beings, whether in health research or in for example psychology. Animal experimentation is also bound by legislation. The prevention of biopiracy and the conservation of biodiversity impose limitations to scientific research. Biotechnology research is restricted when safety issues arise, as is research or field trials using genetically modified organisms. In the medical area sensitive issues have come up leading in many cases to legislation, such as the use of embryos or stem cells. One point to be made here is that legislation and regulations are necessary in all or most of these areas. The tendency one sometimes notes to incorporate these specific areas of legislation into one general legal framework is however one to be avoided. In many cases different sector ministers must be involved or even be leading in such legislation as research may be only one of the activities governed by the respective laws. Agencies or other institutions that must monitor and enforce such legislation will most likely be very different and accountable to different ministers. The other issue that, as is happening in practice, these areas are very well suited to regional and international cooperation. Exchanging views and experiences and creating common resources are highly valuable.

Gathering information for evidence-based STI policies

A last building block for an effective framework for policies for STI concerns gathering evidence about scientific, technological and innovation activities and about the impact of policies. As policies are seen to require increasingly a basis in evidence, and as it is much less easy to collect reliable information on science and technology or research and development than on, say, education, it is important to build up capacity and experience in this area. An Observatory for STI is a common name used for a small body that collects on routine basis statistical information on STI institutions and activities. It must work in close cooperation with the national statistical services as the latter usually will be responsible for actually collecting the data through surveys, certainly when companies are involved. But in quite a few countries an observatory within foe example a national research funding agency has easier access to research in universities than the national statistical services. A considerable amount of 'social' learning is involved in making sure for example that what one measures as R&D really is R&D. The international framework of definitions exists and is very detailed and specific. This so-called Frascati Manual established by the OECD is used worldwide, but quite some experience is required to apply it consistently. As a consequence, it may take quite some time and considerable fluctuations in reported data, before reliable data on R&D in industry or in government labs become available. Much support is available for creating observatories, and there is much scope for regional and international cooperation. A very good example is RICYT, the regional centre for data on Science and Technology in Latin- and Iberamerica. It is an area, moreover, where one will see considerable developments over the next years. More sophisticated and elaborate sets of indicators have been and continue to be developed to better capture the impact of R&D on economic development, and in particular to capture the impact of innovation. In the European Union for example the innovation performance of countries is now measured on a regular basis by using a so-called Summary Innovation Index as a yardstick. Some thirty indicators measure how a country scores in two areas entitled as 'Enablers', namely human resources and finance and support; in three areas that measure 'Firm activities', namely firm investments, linkages and entrepreneurship, and throughputs such as patents; and in two areas which are 'Outputs', namely innovating companies and economic effects. But their usefulness depends not only on the degree to which policy making is sufficiently developed and differentiated, but equally to the degree the actors that actually carry out research and development, the companies, universities, research institutes, intermediary organizations etc, have clear missions, roles and collaboration patterns.

'Performing' R&D: institutions and operating conditions

A simplified scheme to depict the R&D system of a country is shown in the diagram. One finds it basically back in the expenditure statistics of a country. 'Performers' carry out R&D which means they spend the money provided by the 'funders'.



Some large funders may also large spenders, i.e. performers. That is typically the case for companies who nowadays pay in most countries to a large extent for their own R&D efforts. The focus in this section is on the performers, the next section will deal with the funders and their 'agencies' which are in the middle of the diagram. In many developing countries and emerging economies the R&D performing sector is characterized by some key differences in comparison to developed nations.

A vital enterprise sector

The most obvious one is that the enterprise sector usually does not carry out much research. Indeed, historical experience shows that as overall R&D efforts in a country increase, the financial share of enterprises in the total amount of R&D carried out increases as well. The Gross Expenditure on R&D measured as a percentage of Gross Domestic Product (GERD/GDP) which for quite a few countries is now close to or upwards of 3%, is financed for mostly more than two thirds by private enterprises. To the extent that proper economic, social and legal conditions will result in expanding and strengthening the sector of private enterprises one may expect private R&D efforts to grow as well. Yet, there are many things governments can do to promote this. One very effective way is to support companies in employing scientists, engineers and advanced technicians. In many countries schemes exist that subsidise salary costs at a decreasing rate, say from 75% in the first year to 25% in the third year, and 0% thereafter. Often companies retain such persons. Financially supporting specific R&D or innovation projects in companies, after an independent check on likely viability, or collaborative projects between a company and a researcher at a university or public research centre is proven to be effective as well. Technology adaptation and dissemination programmes with a group of companies or an industry branch, supported by a (public) national industrial research institute are another example. Dissemination is indeed one of the fastest ways to increase the skill level and productivity of companies on a wider scale. An approach that has attracted much interest concerns so-called industrial or economic clusters. It is drawing attention in many emerging economies, and increasingly is being discussed in developing nations. The key notion is that there is often a certain specialization of economic activity in a region, whatever the precise size. There is a virtuous circle of 'proximity': companies, even outright competitors benefit from the same suppliers, from agreements and interaction with universities, polytechnics and technical colleges for focused training, from regional governments and banks creating optimal conditions, from joint public, public-private or even private R&D programmes, and so on. Science or technology parks, or public industrial research institutes, with incubator and business development services to assist entrepreneurs in the initial stages of setting up and growing their company, are part of the game everywhere. And very directly, providing tax support, by allowing companies to deduct part of the salary costs of R&D personnel, is found in general by economists to be an effective stimulus. All in all, developing a rich mix of measures and instruments to help increase skills levels, productivity and R&D efforts of companies is a key policy area and challenge for governments in developing countries. Many good examples exist, and countries which are moving fast such as China and South Africa have gone already quite some way.

A more balanced and differentiated higher education sector; public and private responsibilities

The university sector or the higher education more generally, deserves much attention. Many developing countries and emerging economies as well, have seen the sector evolve in a particular way. Often one finds one, by now very large, national university which in the past drew most of the talent in the country, both as professors and as students. As student numbers began to grow new national and increasingly private universities were established. The (former) national university has often grown so large that concerns for decreasing quality are more than justified as funding has not matched the student numbers. Research was rather concentrated at the national university, also because in many cases this university had close links to one or two universities abroad. Private universities concentrate with few exceptions on areas such as business administration, finances, ICT or for example law. Medicine too can be attractive if the middle class of the population can afford to pay high tuition fees. The mushrooming number of small universities has, however, brought a serious quality issue to the fore, making a much tighter accreditation system an absolute necessity. Sometimes, however, governments are still very restrictive with providing licenses to private universities or are in other ways, sometimes unknowingly, raising obstacles. The result is that in those countries gross enrolment into higher education is at a very low level. Public financing is often intransparent and rather more follows historical patterns than funding mechanisms that allocate the scarce public resources in the best possible way. Moreover the national university or the few public ones rather deal with the ministry of Finance than the ministry of (higher) education, creating a further hurdle towards a transparent and equitable system. In countries with a very strong Academy of Sciences the additional problem was and often still is that the development of a strong research capacity at universities was effectively choked. Establishing a more balanced system of tertiary education, which is much less focused on one or a few central universities is essential. Several key policy challenges need to be tackled in a systematic way against the backdrop of expected increase in enrolment. Of course, labour market projections are notoriously unreliable, but it is better to use those figures cautiously in addition to what can be expected on the basis of social ambitions of young adults and their parents, and create a development plan with some realistic quantitative targets for the next decade or more in mind, than allow an unplanned development to happen. Most tertiary educational systems nowadays are a mix of public and private institutions. But governments should explicitly determine what role private institutions can play, what freedoms they need and get (for example in admissions, or in setting tuition fees), whether they are eligible under certain conditions for public funding, and more generally what justification there is to allocate the scarce resources the government has for tertiary education to which functions of public and perhaps some private universities. If in a hypothetical example no good quality public teacher training college would exist, and a private alternative would be proposed, there would be good argument to spend public money. The conditions of course would be crucial. Another example would be in research. Public funding for research could be spent very well at private universities if they would provide the right conditions (available infrastructure for example) and have the best researchers. Would the government have to allow private universities to benefit from any public funding to create the right infrastructural conditions, might be answered however less not so easily. A third challenge is staff development. Often an explosive combination of an ageing teacher population which is not highly enough trained poses a major threat to universities and other tertiary institutions. At universities the norm is nowadays for teachers to have a PhD degree. Governments should work out schemes, together with tertiary education institutions, to increase training levels of current staff, to modernize teaching methods, to assist in recruiting new younger staff by specific retirement schemes, and so on. A fourth challenge concerns differentiation between institutions for tertiary education. Differences mostly do occur, but there is also in many countries the well-known phenomenon of academic drift. In a simplified and somewhat extended version one would say that every tertiary educational institution wants to be a university and every university a research university. The country would not be served by such a development. There are very good reasons to differentiate between universities and institutions of professional that offer shorter (one to two years) degree programmes or diplomas or longer (three to four year) professional degree programmes. Within universities only a relatively limited number should be encouraged or even allowed to developing into or continuing as research universities. Dilution of research funding is a threat all over the world and for example a serious issue in Europe, but much less so in the US. China here follows clearly the US example. Providing good-quality undergraduate education is an important and valuable mission for a tertiary educational institution.

Autonomy and accountability as key conditions

A set of interlinked issues relate to the functioning of institutions of higher education. But the government has to create many of the conditions that provide incentives for individual institutions to improve their management and operating methods. Universities need strong management and the traditional academic procedures for appointing persons on key positions are not always well suited to modern requirements. The same applies to human resource management already mentioned in the context of staff development. Universities and other tertiary institutions need on the whole increased autonomy, including internal financial autonomy and flexibility in employment conditions. Those conditions, at least in public institutions, often resemble those of the civil service, and the recognition that these are not suitable has taken roots worldwide. What governments are increasingly doing is granting autonomy in exchange for accountability. There are several dimensions to this, but a system of quality assurance which provides transparent and comparative information on the quality of education, research and outreach activities (such as community services or technology transfer) that institutions of tertiary education carry out, is at the core. That is often combined with forms of performance-based funding which will be considered in greater detail in the next section. A link to national priorities is another element whether this is implemented through a financial mechanism or not. Governments may require universities to respond to such priorities in ways they may freely choose but should report upon in their annual accounts or strategic plans.

Integrate (semi-) public research institutions

The (semi-) public research sector varies strongly across developing countries. But they are no exception because the same is true for developed nations. Examples have been given of countries that have chosen to concentrate publicly funded research at universities. Other countries prefer to have strong sectoral research institutes. Yet others also have a significant number of academically-oriented research institutes outside universities. Perhaps the best-known example is the German Max Planck Foundation. Countries with strong Academies of Science are not dissimilar, though many of these Academies are still relatively unexposed to pressures to modernize and often down-scale activities. In all cases, however, there is a definite need for governments to include the sector of (semi-) public research institutes in their plans for the structure of the R&D system. Sector ministries may be thought to provide the right sort of umbrella and attention as they define research needs associated with their policies. Yet dangers loom around the corner: civil service employment conditions, a too short-term orientation, low in the hierarchy and on the attention scale of politicians and senior civil servants, a too narrow focus while much research nowadays has many interfaces with other fields of science. Funding is often limited to personnel costs. Yet such research institutes, under ministries, more independently, under a National Commission for Science and Technology or more closely linked to universities can be vital for the country’s development. Energy research, research into water management, environmental research, health research often has very country- specific connotations. So, giving them explicitly attention in a national policy for science, technology and innovation is definitely warranted.

Funding R&D and supporting innovation: institutions and instruments

A contrast between developed countries and most developing countries and emerging economies is not only the availability of funding as such but also the lack of a differentiated and transparent funding system for research and innovation. It may seem a technical matter but it is not. Funding mechanisms play a crucial role in improving quality, in directing researchers and institutes, in ensuring both a sustainable infrastructure for research and dynamics on the basis of competition, as well as in providing incentives for cooperation between universities and companies. As an example, in quite a few developing countries experience is now being built up with a mechanism for providing funding on a competitive basis to excellent researchers and their teams, using (international) peer review as a selection procedure, funding coming from international partners in development.

A differentiated funding system is common practice

Funding for research in universities, as well as for (semi-) public research institutes, can be differentiated into quite a few categories in successful countries. Concentrating first on universities the following may be distinguished. In the first place governments provide from their higher education budgets direct funding, mostly as institutional or core funding to create the infrastructure for carrying out research. There are several ways in which this can be done. Often, also in developed countries this is still strongly based on discretionary ways, which others would describe as arbitrary. But attempts are being made to base these core funding allocations on more or less detailed budgeting and on the funding of specific cost categories. Increasingly governments or higher education funding agencies, which are tasked by governments in some countries to replace governments in doing this, are searching for formula-based lump sum contributions, implying that the governments bases its contribution on some rational calculation (e.g. the number of students and/or degrees granted when it comes to education, or on publications or PhD degrees in the case of research) whereas universities retain the full freedom to spend the money in ways they deem fit. Both past performance and agreed future targets may lie at the basis of such performance- or formula-based funding mechanisms. The second major contribution to university research also comes from the government, but through and independent 'Research Council' (there may be more for different fields of science) and to a lesser degree from an 'Innovation Funding Agency'. This funding is typically provided on a competitive basis, using (international) peer review as the selection mechanism. The proportion between what is often called the 'first flow of funds' to university research and the 'second flow of funds' varies widely. Some countries (the US and the UK are key examples) rely heavily on the competitive mechanism, others put the emphasis on the core funding. It is really a policy issue: continuity versus dynamics, as some would like to phrase the dilemma. In addition a variety of other financing sources are part of the ecosystem of funders. Sector government departments provide funding for projects meeting specific demands, much in the same way as private companies pay for contracts for research. In several countries private foundations or charities are important sources of funding for research; some of them use competitive mechanisms; others are just sponsoring. In developing countries this mechanism is of course well known through the donors. The disadvantage is known as well: it is often difficult for the government to pursue its own development objectives. Individual donations, often incentivized by generous tax laws, can be an important source of funding for specific projects such as establishing new laboratories, buildings or research programmes. The last category of funding that needs to be mentioned are the endowments. There is again a close relation to favourable tax conditions, and if these exist endowments can in some cases be exceptional sources of funding for higher education institutions or dedicated research institutes. The one thing governments will have to realize is that student fees are never part of the equation to fund research. Student loans and grants are an important funding source for higher education, but not for research.

A few data may provide a feeling for the situation prevailing in some countries with advanced R&D systems. In the US total university research is funded for 60 % by federal agencies (such as NSF, NIH, DoE, DoD or NASA), for 7% by the states, contrary to common belief for only 6-7% from industry contracts, and for the remaining 25 or so % from endowments, private foundations etc. In addition in the US out of about 3500 higher education institutions only some 200 carry out 95-100% of all university research. In the European Union maybe a factor of ten more universities have the ambition to be research universities. These data underline the argument

Funding sources for (semi-) public research institutes are not so much different. Most get some sort of core funding from the government; they rely to some extent (usually less so than universities) on competitive funding; especially the institutes with a more application-oriented nature of course would have more income from contract research, and for example endowments play a significantly smaller role.

Key issues for governments with regard to research funding

This illustrates that governments face a number of key policy issues with regard to funding for research. One question is what should be the volume of and the balance between institutional core funding for research and competitive funds. The volume of course depends on what a country can afford at a given stage of development, but the balance is an issue that has to be resolved anyhow. Having no competitive funding is not a good option. In general it makes sense to link competitive funding (and maybe even institutional funding) to national priority areas, but there is a limit to this. Researchers should be encouraged to come up with the highest quality and most original proposals, and peer review should try to select those, and if there is an adequate infrastructure in the country to provide a supportive environment for such research one should be willing to take some risks. A vital policy issue is which mechanism to use for institutional core funding. The situation that history to a large extent determines how much an institution gets, or that it is a matter of discretion, i.e. of negotiations between politicians or civil servants and universities, is not a sound one. How to promote concentration of research and thus differentiation of missions of tertiary educational institutions is a vexing problem that governments in most parts of the world face. With regard to tapping private resources, whether it is for stimulating companies to carry out more research or for attracting private donations for research in public institutions, governments need to consider which tax measures will effectively trigger individuals, private foundations or charities and enterprises.

A funding agency for medium- and long-term research

Competitive funding for research projects is key as a complement to institutional funding. Almost all countries nowadays avail of a mechanism to provide such funding. The National Science Foundation in the USA is well-known example, but as part of modernizing the research and research funding systems many countries have created a ‘Research Council’ or a National Funding Agency whose main task is to make available research money for the best researchers by transparently assessing proposals or past performance through peer review (often international) in competition. There is a good case for letting them operate very largely in a ‘self-organising’ mode by scientists, though the government should set a certain framework to which such a National Funding Agency is bound. The Russian Foundation for Basic Research, the National Natural Science Foundation of China have been successfully functioning during the last twenty years, but also in for example Uganda the Uganda National Council for Science and Technology is now providing competitive grants with government money assisted by the World Bank. Even in France, which in the past relied extensively on CNRS with its own research institutes and research units at French universities, the French Research Agency (AFR) now provides competitive funding. As the STI system evolves and extends governments may wish to consider whether more research councils or funding agencies would better serve different fields of science. The UK has chosen to go this way, and the same is true for the US. But many other countries stick to having one council or agency to fund research in all fields of science, including the social sciences and humanities. The balance between core funding to universities and competitive funds is an important issue but three examples show that no ‘one size fits all’ solution exists. In the US, federal agencies (such as the National Science Foundation or the National Institutes of Health) account for 60% of all research in universities. In the UK, the seven Research Councils spend 2.8 billion £ versus 1.5 billion £ which comes as institutional funding for research through the Higher Education Funding Councils. But in Germany the Research Council (DFG) accounts only for about 20% of all research in universities. Many would argue that 15-20% is a lower bound for ensuring that university research remains dynamic and flexible. On the issue of linking competitive funding to national priorities a large latitude should be given to funding agencies, as mentioned, but international experience shows that funding agencies have increasingly become responsive, e.g. by defining programmes. An example is to be found in Uganda where the National Council has defined about ten broad areas linked to the country’s poverty reduction framework, but proposals in all areas can be submitted and funded, if excellent. And governments in several cases provided large amounts of funding for dedicated programmes for example in genomics research or biotechnology or information and communication technologies or chemistry for sustainable development. The fact that also many developing countries are now considering creating effective funding agencies for competitive research does not obfuscate the possibility for regional or even continental cooperation. Like some other initiatives where an attempt is made to reach out to the best scientists in say Africa or the Arab world, irrespective of their country of origin, one could try to organize competitive funding on a larger scale. This is what is now being done in the European Union where since 2007 the European Research Council operates strictly on an EU-wide basis (including the associated countries such as Switzerland). Many consider this the most important development in European science policy of the last decade, and the best way to promote the highest quality, concentration and dynamism. As a research council or funding agency develops, it will automatically increase the variety of its funding instruments. Four main categories can be discerned. The first one is where it starts: specific projects submitted by researchers. A second category focuses on the career of scientists. Fellowships are provided to accelerate one’s career; considerable grants are given to promising young scientists to set themselves up with a research group at a university and eventually become independent full professors. And the third category promotes networking, traveling, participating in summer courses, organizing scientific meetings, international collaboration and so on. The fourth one is especially important, also in developing countries where the lacking infrastructure for research is a major obstacle. Grants in this category are meant for improving or building up the infrastructure for research, equipment, libraries etc. One way of working towards the same goal of maintaining and updating existing infrastructure is to include overhead costs in research grants. It is becoming common practice to do this, but few countries have so far decided to base competitive research grants on full costs.

An ‘Innovation Agency” to enhance company skills levels, productivity and research efforts
As mentioned before governments can do several things to stimulate companies to increase skill levels, productivity and research efforts. How should one go about it? And what type of support measures is one to consider? Initially for reasons of efficiency and the lack of (human) resources one may well consider to making the same funding agency that on a competitive basis funds academically-oriented or strategic research also responsible for the support measures that target companies in the first place. But eventually as the STI system matures, one usually finds a separate agency tasked with the promotion of research and innovation in companies. The reason is that proposals to get support from companies or involving companies often require some form of business plan, market assessment and a strong managerial approach. Assessing such proposals requires different skills from those required to assess on a competitive basis research proposals. An Innovation Agency would be a generic name. Organisationally, it can be independent though supervised by a ministry of industry or economics, or it can be part of such a ministry. In the latter case one must however be cautious that it can operate flexibly and that politics is kept at bay to avoid politically inspired discretionary decisions or inertia because of political interference. A variety of support activities will eventually develop. Among these are financial support for R&D (or even prototype development) in companies; collaborative research and development efforts of companies and universities/institutes; ‘seed money’ for researchers at universities or research institutes who have the ambition and idea or invention to become an entrepreneur in their own start-up company; support for companies in hiring technicians, graduates or PhDs; putting together business plans with the support of experienced managers; assistance with

intellectual property right agreements and so on. And as mentioned before an important role might be to catalyse or broker links between partners from industry, universities, other educational institutions or government agencies in regions to create clusters.

Mechanisms for core funding of higher educational institutions and research institutes
No magic bullet has yet been found for the core or institutional funding of tertiary educational institutions. That is the case for funding their educational activities and even more so for research. At the same time most countries are moving away from funding based on history or on purely discretionary decisions. The reasons invariably have to do with transparency and accountability. Several approaches are worthwhile considering. Funding education at public institutions of higher education is in some countries linked to output. That means that the number of degrees granted is a parameter which, multiplied by some unit cost, determines how much public money an institution gets. The equivalent input-based formula would simply be the number of students enrolled, again multiplied by a unit cost. A mix of the two of course is also possible. Another option is to take current budgets as the starting point but negotiate performance improvements or maintenance in exchange for sustained or increased funding. One thus adopts an 'incremental change' principle: in three years' time x more students or degrees. Some governments base public funding on budget categories, distinguishing for example between costs for instruction, for libraries, for research, for a teaching hospital, for operation and maintenance of plant, for student services, and so on. Overall, of course key decisions are to what extent governments think students or their parents should contribute to financing tertiary education, to what extent tuition fees are fixed or left to tertiary institutions to set, and what sort of student grants or loans system, and then a public one or a private one through banks), is being set up. Concentrating on the funding of research a few approaches stand out to allocate a given amount of money for institutional research funding to the eligible universities. One is formula-based but very much in the tradition of 'incremental change'. This approach would make some part of the allocation to a particular university dependent on for example the number of PhD degrees awarded, where the unit cost may differ between say natural sciences and engineering or medicine on the one hand and social sciences and humanities on the other hand. The result is some fluctuation of the allocations to different universities in proportion to their performance. Another approach which is being experimented with in Denmark is also based on 'incremental changes' but not on a formula or algorithm to determine changes. Sometimes detailed targets are agreed formally between a university and the ministry responsible for higher education and research. To give a few examples: the number of publications in so-called SCI journals should increase with say10 % on a given period; the number of foreign researchers with 50%; the number of research contract money with 15%; the number of reported inventions with a factor two; and so on. The third approach that merits discussion is based on a mixture of peer –assessed performance and a formula to determine the financial implications. It is no longer based on incremental changes because the fluctuations can very large as there are very strong incentives and penalties. In the Research Assessment Exercise every five years or so universities submit proposals (with information on the size and the quality of the research groups) in areas where they consider themselves to be strong, e.g. in cardiovascular medicine. The Higher Education Funding Councils assess individual researchers on a scale of 5, and compile a 'quality profile' for that particular university in the area of choice. The funding formula then is the size of research efforts in the area of choice multiplied by a unit cost multiplied by a weighted quality index. The weighted quality index is the crucial parameter as a university that would get the maximum score (on the scale of 5) would get seven times the unit cost and another with a middle score only once, and lower scores would result in no funding at all.

Promoting differentiation, concentration and specialization
Governments are also considering which instruments they can use to introduce more differentiation, concentration and specialization, which as mentioned before are important policy challenges for the higher education system. This has lead in several countries to competition not between individual scientists but between institutions as a whole or departments. Sometimes one finds requirements for public-private partnerships in such competitions. Not always is the competition complete. For example in China's case the limited number of universities allowed to participate in the so-called 985 programme have been identified by the government, but using academic performance as an important criteria. Another strategy some

governments adopt especially to increase concentration and also specialization focuses on mergers between tertiary educational institutions. It is not an easy option to implement, certainly not when one part of the problem is the sometimes very large number of rather small private tertiary institutions. Yet governments would do well to consider how accreditation could be used to increase efficiency and quality by increasing the average size of universities and providers of professional training.

A funding system requires consistency and perseverance
Building up a strong STI system is a matter of consistency, focus, dedication and perseverance. To illustrate this box provides some information on the array of funding instruments and concomitant structural and organizational changes China has introduced.

China's rapid creation of funding instruments

Initially a large number of R&D Programmes have been set up aimed at developing and/or disseminating high-tech and traditional industry technologies, involving universities/academy institutes. Examples are

- 1984: National Key Technologies Programme
- 1984: State Key Laboratory Programme: now 189 labs
- 1986: 863 Programme (National High Technology Programme: 19 areas)
- 19886, 1988: Spark and Torch Programmes (Rural Areas/Agriculture; S&T Industrial Parks; business incubators)

Afterwards academically-oriented research was addressed

- 1997: 973 Programme (National Programme on Key Basic Research Projects)
- 1986: Establishing National Natural Science Foundation of China

More recently major reforms of the Chinese Academy of Sciences have been introduced and the Academy continues to play a leading role in R&D; also the role of the Chinese Academy of Social Sciences continues

In a parallel move universities have been reformed and strengthened including a reduction of the role of central government and internal governance reforms in 90-ies

- 211 Programme (1995) to create 100 leading universities
- 985 Programme (World-Class Universities Construction Programme:1999, second phase 2004) to select from previous 100 a smaller number (38)

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often a mix and quality assurance is here taken to represent all activities undertaken in this context. Autonomy is increasingly provided in exchange for accountability and the latter hinges to a large degree on reliable quality assurance mechanisms to be in place. One important component of such a system of quality assurance is a formal accreditation system for higher education. Many countries nowadays require that individual programmes (an undergraduate or graduate programme in chemistry for example) and/or institutions as a whole are accredited on a regular basis. Every five years or so, a 'stamp' has to be obtained. Public funding (in the case of public institutions) or the license to operate (in the case of private institutions) can be made dependent on a positive outcome, though in both cases some feel that market information (in the form of the outcomes of accreditation reports, put otherwise: naming and shaming) available to students will do the work without formal sanctions. Not all countries have a national system; some depend on professional bodies (for example in engineering) to do the accreditation. But the mechanism is basically the same: the institution (or department or programma management) is required to carry out a self-evaluation – retrospective and prospective – according to a strict protocol; an accreditation committee appointed by the accreditation body carries out a site visit, and writes an accreditation report with possible suggestions or even requirements for improvements to be made before the accreditation body gives its verdict. Setting up a proper, transparent and independent accreditation system is one of the urgent challenges for governments in developing countries, and it is a very positive development that this is now

happening on a significant scale. It is also an area where there is quite some scope for regional and international cooperation to exchange views, to establish common protocols, to get international experts on board for national accreditation exercises, and eventually maybe to set up joint accreditation systems. On a global level one finds the International Quality Assurance Association for Higher Education, the INQAAHE with membership from all over world from developed countries, developing countries and emerging economies. For research much less homogeneity exists in quality assurance mechanisms. They are straightforward in the case of funding agencies providing competitive funding as the evaluation is the key element in the selection and granting process. But for the core or institutional funding component of research at universities or research institutes practices still widely differ, or are even absent. Yet, increasingly governments take the view that public funding has to along with regular evaluations of performance. So more and more one see governments appointing committees to do an evaluation of research institutes in a similar vein to the accreditation process in education: a self-evaluation, a site visit and a verdict with or without direct financial or other implications (including dismissing management). In other cases governments just require that institutions themselves or umbrella organizations organize take responsibility themselves for such an evaluation but then provide governments with the outcomes. The yardstick along which to measure and evaluate the performance of a research organization is of course dependent on the nature of the institute. An institute for clinical research, an institute for industrial research or an institute for agricultural research that may involve a considerable extension component, have different audiences and clients, require different criteria for evaluating and their clients must be strongly involved in assessing performance.

A crucial enabling factor: Information and Communications infrastructure.

Establishing National Research and Education Networks; telecom competition
A marked difference between many universities and research institutes in developing countries and those in developed nations is found in the area of information and communication technology support. The dependence of education, especially higher education, and research on being heavily supported by a variety of tools in the area of ICT, is nowadays so great that no catching up will be possible without adequate provisions. One needs computers in large numbers, software tools, management information systems, one need to train people to use all of these. Here attention will be focused on one provision that has become of paramount importance in the last two decades, namely a network that provides high-quality data communication services. In all developed countries and in many others ne finds dedicated national networks for research and education, NRENs. These are ‘knotted’ together by continental and global links (very high-capacity cables, increasingly optical fibres). Locally the national networks are connected to the local campus or wide area networks. The reason that dedicated networks exist is twofold: as long as there is no commercial traffic over the data networks special arrangements can be made with telecom operators, and research and education pose such heavy requirements that it is interesting for telecom operators to use them as test beds for new developments. In many developing countries the local capacities are not high, national connectivity is poor as is international connectivity. The other side of the coin is that costs are very high and reliability low. There is no reason why that situation should be allowed to persist. With the new undersea cable along the coast of East Africa, global coverage of the system of backbones is virtually complete. What remains is to build the national systems and connect them to the continental and global backbones. Governments should make it a priority to do this. It requires two very different sets of actions. The first is not in the hands of ministers responsible for science, technology and innovation. It is deregulating telecom markets. As long as (quasi-)monopolies are allowed to continue, no solution is possible. Several years ago, even in Europe, where negotiations are necessary with telecom providers in each country to complete the paneuropean backbone, prices differed by a factor of 70 existed between ‘monopoly’ countries and those with the strongest competition. So huge gains are to be obtained and this will help governments in their second role: they will have to provide additional funding to create and operate the networks. Eventually subscriptions must be paid by tertiary educational institutions and research institutes, but that leads back to the issue of sustainable funding mechanisms.

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