Challenges for the future: The evolution of science, technology and innovation policies

Rigas Arvanitis

We present some of the main changes that have occurred in the recent decades that have modified the demands toward science and technology. A new institutional and economic framework has been set-up where knowledge becomes the most important resource: more direct and aggressive participation of the private sector, where R&D becomes an economic activity and not just an auxiliary to other sectors; increasing demands and pressures on the environment; more active participation by the public in decision making and precise demands in many related areas; networking and globalisation of the economy all modified profoundly the ways science is done and the way policy is conceived. Limits to these challenges include the functions of the context where technological activities are developed. Learning, in all its forms – in companies, schools, and all working environments- appears to be pivotal to the "knowledge economy". Companies also learn, but this cumulative and collective learning seems very much limited to within the particular company. Policy has to challenge the socialisation of this learning. Moreover, infrastructures, not so much in terms of concrete and steel constructions, but rather as a complex web of norms, protocols and standards, play an increasing role. Science and technology policy needs to develop flexible and stable data standards, and provide the necessary means for the generation of protocols (both social, in the form of international agreements about data exchange, and technical, in the sense of metadata standards). Scientific careers will need restructuring in a context where the public and the private research activities will become more and more closely related. This represents a fundamental change in the policy-making motivations and needs. Innovation policy is now central to policy-makers, not only because of the need to fight against market failure that leads to under investment in R&D, but also because new competences are the product of this interplay of social and technical forces. And when science, technology and innovation are closely related, the technical objects, and R&D programmes redefine the international dimension of the work. Networks and research and technical collaborations seem to be the new norm for scientific work. It seems that gathering different actors responsible for technological development at the regional level within countries will become the basic unit for international action. International organisations and funding bodies will have a new role to play, and the procedures they develop will play a paramount role in this new context. The implications for the future of this tension between private demands and civil society's action, and between the support of specialisation and technological development and scientific diversity are examined in the light of the current evolution of policy around the world.

I. Introduction

The paper will reflect on some of the new dimensions in science and technology policies that emerged during the last years of the twentieth century. I will argue that the new and complex issues at stake are not unconnected to very fundamental institutional issues. I will try to figure

out some "mega trends" in policy issues and possible responses to the challenges posed.[1]

The context of research has largely changed in the last ten years and the issues at stake are more controversial than ever. Issues such as environmental pollution, toxicity and standards in food and agriculture, or new processes and products, such as new breeding techniques, biotechnological production, bioengineering, new potentially hazardous products, privacy issues in information exchanges, seem to challenge the traditional scientific contract between researchers and the polity. This contract stipulated that researchers would do their best to the extent to which they are correctly funded. Some separation between the basic and the applied research was implicit because basic research was considered universal whereas applied research would be essentially for profit. However, this contract has been fundamentally challenged.

As the private R&D laboratories of large companies undertake more research than public or university laboratories, the motivation for research seems to clearly be for profit. This "privatisation" of research has been characterised as a new mode of knowledge production, "mode 2", which is mostly based on transdiciplinary areas of research.[2] In some areas, for example agricultural or health research, this change has been very extensive[3] and has affected both large industrialised countries and developing countries alike.

The question is basically one of control. The researchers' responsibility is exercised more than ever, both ethically and juridicially. The public holds scientists accountable for the consequences of the use of new technologies, a new prospect for most researchers who were not previously held responsible for the misuse of science. So scientists are called upon to exercise prudence and are obliged to discuss who should define and control the research agendas. The state and public authorities; the firms or the public, through some participation mechanism? Fortunately, today scientists are to be found in all these arenas and can no longer be considered as a specifically different social body: they are found in schools, universities, public labs, private labs, NGOs and activist movements and are thus more eager to debate these issues than twenty years ago.[4]

However, here we want to stress some of the basic consequences of these changes, without reverting to mere wishful thinking, but relying on

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[1] These ideas and debates are partly based on the work done for section 1.30 (Science and technology policy) of the *Encyclopedia of Life Support Systems,* section edited by the author (to be published in June 2001). See in annex a brief overview of the section. The author wishes to thank contributors to the Encyclopedia section of Science and Technology Policy. See annex for a brief content of this section. A slightly different version of this has been also presented at INES (International Network of Engineers and Scientists for Global Responsibility) International Conference *"Challenges for science and engineering in the 21st century",* Stockholm, June 2000.

[2] Gibbons, M., *et al., The new production of knowledge. The dynamics of science and research in contemporary society*. 1994, London: Sage.

[3] Current Issues in Agricultural Science and Technology Policy, *G. Middendorf, E. Ransom and L. Busch (Michigan State University, USA),* article in EOLSS Encyclopedia. And it is a change apparent even to laymen. See the magnificient novel by John Le Carré, *The Constant Gardener* (2001) on the dangers involved in the privatisation of pharmaceutical research.

[4] INES (International Network of Engineers and Scientists for Global Responsibility) is one such area of discussion. But see other NGOs on the same topics as for instance the Loka Institute (http://www.loka.org).

economic —and political— arguments, and make a case for the defense of "public" research, that is research not directly attached to the profits of a particular firm. We believe that this discussion particularly affects newly institutionalized research environments where research roles have their roots in the academic environment. It also affects countries such as China, Brazil, Mexico and South Africa, which are engaged in rapid industrialized change and have relatively large scientific communities.

II. Some immediate challenges to scientific practice

1.Research is becoming an economic sector

Research is becoming a new economic activity *per se*. Research can no longer be understood as partner subordinated to other economic and productive activities. It is a supplier to the industrial and services economy. If we consider research as an *economic sector*, then we have to accept that the economics of any normal industrial activity apply. This is clearly the case in most industries – for example, telecommunications, informatics, new materials, and computer sciences. In becoming a predominant supplier, research accounts for a large part of the evolution of the industries and services. The way this "new" sector of research interacts with the rest of the economy should then also become a very crucial aspect of the new economy.

Since the economists have given careful consideration to the innovation process, the role of R&D has been acknowledged as crucial. R&D is the single most important indicator of engagement in the development of technologies. R&D is tightly linked, but not exclusively so, to innovation. In fact, few authors would dare say that innovation relies entirely on R&D. Innovation is too complex a process to be limited to the input from R&D activity alone. Innovation lies in an intertwined series of causalities, which can be described by the networks that are constructed by the designers and users of innovations.[5] The more complex these networks are, the more fertile the terrain of innovation is. Inside companies, innovation becomes "manageable" insofar as these networks can be made to fit the strategy of the firm, but across the sector the linking of multiple types of institutions is the name of the game. Public and private spheres are used to promote a particular product, process or idea. R&D is only one out of many elements of these networks.

As the process technologies become more and more complex, as they include more and more technologies from different sources, as they grow, sometimes inadvertently, beyond the abilities of the employees of a company, research becomes indispensable. In addition, the products that are conceived of in industries, such as fine chemicals, polymers, biotechnology or information engineering, are likely to impact on the more intimate aspects of matter and life and need a more refined knowledge than before. Finally, the competitive pressure on companies compels them to introduce more product innovations. Science and technology consequently have a much closer relationship than before, as the indicators of these trends clearly shows: patents cite more and more

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[5] Callon, M., Variety and irreversibility in networks of technique conception and adoption, in *Technology and the Wealth of Nations*, D. Foray and C. Freeman, Editors. 1993, Printer: London. p. 232-268. Latour, B., *Science in Action*. 1987, Cambridge, Mass.: Harvard University Press.

scientific articles, and vice-versa[6], and university laboratories participate more than ever in technological programmes and profit from it.[7]

Interestingly, a paradox lies in this growth of R&D, which I'd like to call *the paradox of R&D development*. As R&D gets more important in the development of economic activities, other economic resources, beyond the ones needed by R&D, are called upon. The more there is a need for R&D, the more there is a need for all the other economic activities that surround R&D, all other non-research activities. Even at the level of a single company, the research activity in a company is not usable until it is "formatted" to its the needs and a lot of effort needs to be expended before a the company's need for R&D is readable. This means, that the object and the results that emerge from the research activity need to be enclosed by numerous other activities that guarantee the research to be included in the productive and commercial process. A large part of this is covered by the *development activity* of R&D. The engineering and technical adaptation of the technologies to the existing mix the company is using is thus a long and costly process (see below).

R&D needs to be surrounded by all the other activities that permit the company to identify useful projects, convenient for the company, and "do-able" in terms of resources and means. All these activities, usually qualified as "complementary assets"[8], are probably even more important in order to maintain the R&D activity, than the proper work of the researchers and engineers.

More R&D implies more development and more "complementary" activities. In short, R&D is becoming an economic sector *per se*. As in any economic sector, the absence of adequate investment in the necessary assets precipitates a crisis. Economists agree upon only one thing about R&D support: the market forces will under-invest into research. The reasons for this have to do with the costs and risks involved in R&D, like any other economic activity, but can also be attributed to the erroneous view that R&D is an additional activity, and not the principal activity, which the new situation requires. Unfortunately, economic analysis has not yet mustered enough arguments for this new view. Thus, for the time being, it is sufficient to state that *the defense of research goes hand in hand with the defense of other economic activities that accompany of research*.

2. Globalisation and industrialisation: the context of knowledge

Globalisation, that is the extension of markets worldwide and the appearance of large international issues and commercial activities are a new area of political and institutional action. Unlike the former extension of national activities in foreign markets, we are seeing the appearance of a whole new range of activities with a geographic scope that is international *by definition* (R&D being one of them). Action in these markets and in these new settings is effective to the extent that the scope of competence

[6] Hicks, D.M. and S.J. Katz, Where is science going ? *Science, Technology, and Human Values*, 1996. 21(4): p. 379-406.
[7] Etzkowitz, H. and L. Leydesdorff, eds. *Universities in the Global Knowledge Economy. A Triple Helix of University-Industry-Government Relations*. 1997, Pinter: London. Godin, B. and Y. Gingras, The place of universities in the system of knowledge production. *Research Policy*, 2000. 29(2): p. 273-278.
[8] Teece, D.J., Strategies for capturing the financial benefits from technological innovation, in *Technology and the Wealth of Nations*, N. Rosenberg, R. Landau, and D.C. Mowery, Editors. 1992, Stanford University Press: Stanford. p. 175-205.

of the institutions is global itself.[9] The rise of a new institutional framework with global action is still limited but is already underway.

In scientific and technological activities, globalisation can be exemplified in many areas: environmental issues, R&D and technological development agreements, deregulation of commercial areas with strong technological components, such as telecommunications, patenting and the protection of intellectual rights. It should be underlined that many of these issues have at some point been the object of international negotiation in the WTO, or in the constitution of international or regional economic areas such as NAFTA, Mercosur or the European Union. In these arenas the active participation of large corporations that are dominating the international scene is quite evident.

A good example of this is that of international environmental negotiations.[10] Since the Montreal Protocol (in 1989) where one large private company decided to ban ozone-depleting gases, trans-national corporations have become the main players in the "*sustainability game*", opened-up by the 1987 report of the Environment and Development Commission of the United Nations, known as the *Brundtland report*. There is still no quantifiable definition of sustainability, but all pollution abatement and pollution prevention measures seek to expand the existing resource base through environmental management and need basic scientific and technological research. So research here is really at the forefront, along with pollution prevention and the more severe application of environmental norms.

The concept of sustainability gave rise to the large international conferences at Rio (1992), Kyoto (1997), Buenos Aires (1998) and The Hague (2000). These conferences not only tried to fix levels of maximum emissions of CO_2 or other gases; the proposed norms that would permit to fight pollution or even prevent pollution, but they were also the arena of fierce international debate and a split between richer countries and developing countries occurred, which has been progressively consolidated. More importantly, new institutional actors appeared. They have largely been promoted by large corporations and industries with global scope: the chemical industry and its International Council of Chemical Associations (ICCA), created an initiative known under the name of Responsible Care; the crop industry created The Global Crop Protection Federation (GCPF); and the International Council on Metals and Environment (ICME), created the ICME Environmental Charter.

Beyond the paralysis of the large international negotiations, the larger world companies have created the conditions for a new market, based on environmental "rights to pollute", a concept that has been very much challenged by environmentalists. It is quite predictable that the large corporations will promote this international market thereby reducing the risk introduced by "environmental-friendly" innovation and, at the same time, promote their own rules of the market in international trade and technology transfers. The reason for this massive mobilisation of large industrial corporations is that the reduction of environmental problems

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[9] An example of inadequacy of scope of competence is the legal fight against corruption, and international illegal trafficking such as tax avoidance, drug trafficking, international prostitution or other unlawful activities that are international by nature. Judges, mainly in Europe, have largely contributed in pointing out their inability to make efficient investigation on these activities because of the absence of an international system of law suitable for such cases.

[10] Micheli, J., Fin de siglo: construccion del mercado ambiental global. *Comercio Exterior (Mexico)*, 2000. 50(3): p. 187-195. Also article in the Encyclopedia EOLSS.

will need extensive investments in innovation. It is clear that in order to meet the new anti-pollution standards, in air and water pollution, and waste reduction, industries will have to accelerate the pace of introduction of "end-of-line" technologies: mechanical and chemical filters, bio-filters, scrubbers, catalytic exhausters and all kind of new techniques. In order to reduce these high costs a profound revision of the production process is needed in order to prevent pollution, rather than merely reduce it after production. Radical innovation is urgently needed, for example, in introducing paints and lacquers with no solvents, aerosols without CFCs, batteries without cadmium and mercury, and also in modifying industrial processes that will reduce the consumption of water , energy and natural elements in the production processes.

Apart from these product and process innovations, the environment also poses a challenge in terms of institutional and legal organisation. Industries have to change their management of their relations to communities; environmental NGOs - now a major player in the game – must be drawn in, and other pollution risks are appearing which need to somehow be confronted. Additionally, all international organisations have now insisted that the reduction of poverty reduces environmental difficulties to a greater degree than the control of anti-pollution policies. In fact, all environmental problems are the result of our developmental, industrial and agricultural conception. This explains why scientists' participation and R&D is so important.

Globalisation additionally means the arrival of new competitors. This applies mostly in the case of Asian economies and other "emerging" economies. "Emerging" here, means in financial markets, or new financial opportunities. The risk is higher because the stakes are higher, not only because we are in a new market, where there are no real patterns, but also because there are fewer actors and so upward or downward movements depend much more upon the activities of a very few, specialised investors or decision makers. This game is dangerous, as many recent financial cracks have shown. "Emerging" economies are something different: they are economies that have invested heavily in industry and technology. Based on the idea of "catching-up" with the industrialised countries through the development of highly efficient industrial sectors mainly oriented toward exports, these countries have concentrated on the technological upgrading of their industrial sectors.

Each of these countries has chosen different sectors, but all have been using a very strong interventionist model accompanied by active private initiatives. What is important here is not the absence or presence of state intervention; the important variable seems rather to be the co-evolution of state intervention and private action in support of education, technology and science (in that order). The examples of the Japan or South Korean are illuminating[11]. Industry and technology have been actively supported by the State, who designed the industrial policies for specific sectors. Massive economic support, important measures designed for upgrading the productive processes and accessing the information were designed. A specific technological agency was set-up and priority was given to engineering and technological areas of research. As in Japan, South Korea has learned to manage industrial technologies designed elsewhere: "reverse engineering" and "improvement engineering" have been the key paths for learning in these two countries. A large domestic technological

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[11] Amsden, A., *Asia's next giant: South Korea and late industrialization*. 1989, London: Oxford University Press. Kim, L., *Imitation to Innovation: The Dynamics of Korea's Technological Learning.* 1997: Harvard Business School Press.

capability has been built through intense technology imports and technology transfers directly integrated into the production. In both the Japanese and Korean cases, large firms have been the targets of these policies — but this is not the case in Taiwan or present-day China, as very large Chinese firms are still much smaller than their international counterparts[12].

It has been claimed that these new competitors appear neither in very innovative sectors, nor with technologies that could really be said to be breakthrough (textiles, metal-mechanical industries and plastics). This is the case in fact when there are no really strong links between economic, social and political interests on the one hand and scientific activities on the other hand. Recent work in Brazil and Venezuela[13], show that in economic sectors with strong financial support, such as in the petrochemical sector in Brazil or the refining and exploration of petroleum in Venezuela, there is room for real breakthrough innovation and consequently important research and scientific advance in areas such as chemical engineering or chemistry. Again, the examples of semiconductors in Korea or Taiwan exemplify the possibility of technological breakthrough in countries that were not seen as potential technological stars thirty years ago. Another well-known example is that of the growing informatics sector in India, although support is rather low and the working environment rather difficult to manage.

Whole industries are emerging that rely upon sophisticated technologies but which are not destined for their domestic markets. The radical difference here in the unequal exchange denounced some 50 years ago by CEPAL economists in Latin America is that exports are composed of highly sophisticated products, and not primary agricultural products such as coffee, cocoa, peanuts, soya beans or bananas. The real challenge now is to establish whether this "*maquiladora*" system or similar types of "offshore" production — for example the special economic zones and the "*sanli yipu*" companies in China — can be the leverage point for more technological development[14], as these companies are embedded in an international export movement, rather than a national development plan, and thus depend upon forces they do not master for their success. Once again, on-going technological development lies in the possibility of a more fertile ground for knowledge production, in the development of the new economic sector where R&D is the central activity.

It should be noted that the process of economic globalisation has been accompanied by a reduction in the role played by large international

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[12] See articles of Yukiko Fukasaku and Sachiko Ishizaka on Japan, Gu Shulin on China in the EOLSS.

[13] Furtado, A.T., Technological competition in deepwater: the success of a company in a country in the periphery. *Science, Technology & Society*, 1998. 3(1): p. 75-109. Vessuri, H. and M.V. Canino, Sociocultural dimensions of technological learning. *Science, Technology and Society*, 1996. 1(2): p. 333-349.

[14] Carrillo, J., ed. *Reestructuración industrial. Maquiladoras en la frontera México-Estados Unidos*. Regiones. 1986, Consejo Nacional para la Cultura y las Artes, Colegio de la Frontera Norte: México. Hualde, A., Saberes productivos y polarización en la Frontera Norte de México. *Sociología del Trabajo (España)*, 1999. 37(Otoño 99). Carrillo, J. and A. Hualde, Maquiladoras de tercera generación: El caso de Delphi General Motors. *Revista Espacios (Número especial sobre Aprendizaje tecnológico y gestión tecnológico, editado por R. Arvanitis y E. Medellín)*, 1996. 17(3): p. 111-134. Micheli, J., ed. *Japan Inc. en México. Las empresas y modelos laborales japoneses*. 1996, Miguel Angel Porrúa: México. Delphine Mercier. *Circulation des savoirs dans les maquiladoras du Mexique*. Thèse de Doctorat. Université de Saint Quentin en Yvelines, 1998.

political organisations born out of the Second World War, such as the UN system. Instead, commercial or economic instances of negotiation, born out of economic interests, have largely dominated the scene. The USA, because of its hegemonic position, has played an important role in the diminishing importance of organisations such as UNESCO or the UN. In turn, the void created by the retreat of international organisations, the need for immediate urgent relief action for refugees and very exceptional crises provided the opportunity for NGOs to grow.

Today, NGOs engage in more long-term action and are not limited to urgent relief only, as exemplified by the "French Doctors" (*Médecins sans frontières*). Something very similar has happened in research, probably most evident in Africa.[15] NGOs and international institutions largely cooperate today however there is generally consensus that large international scientific institutions need to reevaluate their role. Up to now, these institutions, such as UNESCO or FAO, have been effective in designing large projects for institution building. Smaller international organisations like the International Foundation for Science or the Third World Academy have been more effective in giving support to international scientific cooperation and specifically oriented research programmes. Also, donor agencies such as the former USAID, the IDRC in Canada, RAWOO, DANIDA, SIDA or French Cooperation have been major actors in scientific collaboration.[16] All these institutions have played an important role, but without any vested interests in or links with the more rapidly expanding levels of commercial negotiations.

Up to now globalisation has profited the richer countries and the larger corporations. International technology transfers are more common between the USA, Japan and Europe than with the rest of the developing world. This flagrant inequality has been repeatedly criticised. It has to do with the fact that transnational firms are responsible for most of the high technology exports, mainly as a result of exchanges between subsidiaries. Instead of simply arguing about this inequality, one has to take into account the fact that globalisation is a concept that is subject to limiting factors such as the real learning capacity of a particular economy and of its production units, which define the context of international transfers of knowledge and the real costs associated to knowledge creation, absorption and diffusion. If technology transfers are limited this can be attributed to the limits of the ability of firms to integrate the new resources. Entrepreneurial activity, based upon the development of medium and small-sized companies, with support of the state on technical grounds may be a viable solution, as exemplified in some industries and countries, but in no case can it be the sole solution.[17]

3. Knowledge economy means schooling

If we take seriously the idea of a "knowledge economy", then we have to also accept that an economy needs learning mechanisms and institutions.

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[15] See Roland Waast, S&T Policies in Africa, article in the EOLSS Encyclopedia.

[16] Gaillard, J., *La coopération scientifique et technique avec les pays du sud. Peut-on partager la science?* 1999, Paris: Karthala. Gaillard, J. and L. Busch, French and American Agricultural Science for the Third World. *Science and Public Policy*, 1993. 20(4): p. 222-234.

[17] A good example of a country that promoted SMEs is Taiwan. See Hou, Chi-Ming and San Gee (1993). National systems supporting technical advance in industry: the case of Taiwan. National Innovation Systems. A comparative Analysis. R. R. Nelson. New York & Oxford, Oxford University Press: 384-413. Mexico is an exampke of a system relying mainly on large firms, see Cimoli M., Ed. (2000). Developing innovation systems: Mexico in a Global Context. London, Pinter.

Education here is at the forefront. Repeated difficulties in amending the educational system -not only in developing countries- have far-reaching consequences, beyond the educational system itself. One suggestion has been to try to couple the educational system with the needs of the economy. This claim is usually supported by social scientists for a variety of reasons (timing of educated generations that differ from the timing of needs of industry, necessary strengthening of basic skills needed for all type of social activities independently of specific competencies, the need to maintain and promote innovative activities by educational institutions not promoted by firms, etc.). They have also demonstrated that educational systems have other social roles to play, apart from bringing an educated workforce to the labour market. For instance, education plays a cohesive role, an identity forming role, etc. More generally, education brings a necessary feeling of sense about how things work out. Schools also operate as a social screening device for the schooling population. This social selection process and the fact that schools have been traditionally the vector of ideological work and the vector of political proposals, make it difficult to discuss.

Proponents of the "coupling" of education to a specific economic activity argue that if one tailors an educational secondary schooling programme for, say, foundry, it will probably have to do with the workforce in the metal-mechanics industries as well as with social cohesion (a word very much favoured in Europe where unemployment has provoked a real social crisis). But in practice, there are difficulties in the process of defining what type of precise skills are needed, mainly because industry is not able to provide such information. This definition of competencies is related to the learning capacity of a firm. Thus companies with a poor register of innovation or a feeble management of technology will have more difficulty in defining the types of profiles of employee they would like to hire. Moreover, the process is plagued by the increasing heterogeneity of the industrial sectors, where needs in a technologically similar area — as for example chemistry of metal-mechanics — are expressed by variety of types of companies.

Many observe that it is more difficult today to define which schooling methods are most appropriate, what role lifelong training should play, and what the best division between professional training and general education is. All these questions are generally also posed in the absence of a real demand from the potential employers. An enterprise rarely knows what exact qualification qualities are required by a future employee; on the contrary, they seem to know how to define the social qualities needed better. This holds true both for lower and higher employment posts. Human and social qualities, such as the will to learn, appropriate attitudes toward authority, and the social aptitudes of a candidate are usually more important than his or her mere qualifications. Little is known about how school does or doesn't provide attention to the acquisition of these "qualities". In the case of engineers in Mexico, it has been shown that large companies favour the private universities, not on the grounds of competence, since better engineering curricula are found in public universities, but because the graduated engineers from private schools and their counterparts in higher management posts in the firms are in a closer social proximity.[18]

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[18] **Ruiz Larraguivel, E., *Formación, profesión y actividad laboral de los ingenieros de la industria manufacturera. El caso del Area Metropolitana de la Ciudad de México*, in *División de Ciencias Sociales*. 2000, Universidad Autómoma Metropolitana - Xochimilco: México.**

4. Companies also learn

So far we have talked about individual learning. What happens with collective learning? The bulk of what economists call *technological learning* is about firms learning how to use, maintain and develop a technology. Companies do that in order to stay in competition. In some cases the management of their technical capabilities is a real difficulty. Some of the conclusions of these observations are useful to our reflections.[19]

Technological learning, which can be primarily understood of as the experiences a firm goes through, is a collective process, accumulative over time and very specific to a given working environment.[20] These three characteristics have to do with the timing of the technology transfers and the difficulties of transferring a technology from one country to another. These characteristics also explain why it might be easier in some cases to begin from scrap, "reinventing the wheel", rather than to try to change an old productive system. As economists now accept, the adaptation of technology is an important path by which new technology can be developed. Thus, learning occurs when changing from one site of production and conception to another site (which implies a technology transfer) and some of the main characteristics of the technologies, such as size, scale or industrial layout, are changed. The fact remains that the complexities of technology transfer lie precisely in the learning mechanisms embedded in a firm, which in turn are linked to specific activities.

In addition to these internal learning mechanisms, firms more often than not devise alliances with other firms in the same sector or with their productive suppliers.[21] This phenomenon of technological alliances is probably the real difference between the situation now and some twenty years ago. This is evident from the widespread emergence of technological alliances, that is, cooperative agreements between any combination of firms, universities, government laboratories, government agencies, and other such entities.

These alliances facilitate the sharing of costly equipment and research facilities and the building of common research and development teams and thus enhance technological and scientific knowledge. Alliances are also intended to diminish risks and to secure a presence in future technological development, although the outcome of an alliance may constitute a high risk by itself. Alliances are often used for pre-competitive work, that is, the development of a technology at a stage before its full commercialisation. In such cases, there is always the risk of creating competition, particularly in alliances of multiple firms. As all members of alliances have their own individual interests, they may compete to achieve them. Members of alliances may be companies that are profit-motivated, but may also be research entities with no profit objectives, as in the case of universities,

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[19] A collection of studies on technological learning are to be found in a special issue of Science, Technology and Developement, vol.3(1), 1998. See introduction : Arvanitis, R. and D. Villavicencio, Comparative perspectives on technological learning: Introduction. *Science, Technology & Society*, 1998. 3(1): p. 1-9.

[20] Villavicencio, D. and R. Arvanitis, Transferencia de tecnología y aprendizaje tecnológico: reflexiones basadas en trabajos empíricos. *El Trimestre Económico*, 1994. 61(2): p. 257-279.

[21] Vonortas, N.S., *Cooperation in research and development*. 1997, Holland: Kluwer Academic Publishers. 288. Arvanitis, R. and N. Vonortas, Apprentissage et coopération à travers la Recherche-Développement. *Technologie, Idéologie, Pratiques (T.I.P.)*, Septembre 2000.

most government services, public research institutes and so on. What really makes the difference is not so much the profit-making objective as the internal organisation of the different parties. Public institutions have different rationalities and budgetary constraints from private companies. The timing of productive activities also differs between universities and companies. The latter usually have stricter deadlines and follow calendars under the pressure of market activities. These different organisational characteristics may pose problems in carrying out the practice of the research activities, and also in the use of research results.

Governments play an active role in promoting and inhibiting alliances, and may also take an active role within alliances. Allying non-profit making entities with firms can also blur the definition of a firm. A government laboratory or a university can secure continued funding by successfully meeting the firm's innovative goals, but in so doing may have, in effect, become motivated by the same profits that motivate a firm. A similar blurring of distinction occurs when policy promotes or allows patenting by publicly funded researchers, or the licensing of publicly funded innovations.

Alliances can be made between a large number of firms, and thus can bring about complementary or adversarial alliances, complementary alliances being those where companies rely on each other in the development and use of the technologies. Providers and clients are thus joined in a common endeavor. Alliances that associate firms in the same industry are less common precisely because of possible competition in the use of the resulting technologies.

Evidence of how successful these learning mechanisms are, are the companies in many countries that have become very successful in developing products that were previously unknown, even if these products are exclusively for export markets. In developing productive processes, these companies have thus learned to manage a new technology. They can enhance their capacity to absorb and manage more complex technologies and because a company does not operate in isolation, its suppliers or users may also learn to manage new technologies. The *maquiladoras* in Mexico, or companies in the free zones in Mercosur or Asia are good examples of these cases.[22] Formerly simple companies that were merely assembling parts provided by foreign providers for foreign clients, some *maquiladoras* are today becoming efficient productive units. Indeed, some of the more innovative firms already have a good record of experiences in many related areas. Learning has been their *motto* and the companies have benefited from having a large range of contacts with their environment. The links they have established with their partners in R&D or other areas, abundantly documented[23], are the probing tools of companies, via which they can expand their experiences, their possibilities and eventually test new technical and productive solutions.

5. Users demand more participation

As the impacts of the new products and technologies becomes felt more strongly on everyday life, citizens become more aware of the role research plays and are willing to participate more actively in the definition of the

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[22] See references in note 14.

[23] See references in note 19 as well as a special issue of *Journal of Technology Transfers* edited by R.Arvanitis and N.S. Vonortas, Technology Transfer and Learning Through Strategic Technical Alliances: International Experiences, Special Issue. *Journal of Technology Transfers*, 2000. 25(1): p. 9-12.

research orientations. This new political demand, although it has its origins in movements resistant to large technological projects, is now trying to define the contours in a more institutionalised way.

It is a move of particular importance for scientists because science users are no longer only other scientists. In fact, we are currently seeing the span of the users of science growing enormously. As our life styles become increasingly affected by technology, for example, mobile telecommunications, cable TV or prepared food technologies, pressure from the public increases accordingly. Previously, the demands of the public were largely reinterpreted by experts acting on behalf of industrial producers. However, it is imperative to note that "consumers" are a vast assemblage of different types of demands and can no longer be reduced to a standard consumer. The era is long past when Henry Ford stated that he could satisfy all the wishes of his clients with regard to the colour of their cars as long as it was black. Users are a complex group, difficult to anticipate. Today they are more educated, ask for more and know that engineers try to respond to their perceived needs.

The public has exercised very strong pressure after large industrial catastrophes, or technical and scientific accidents. Laypeople have been calling for decision-makers to take responsibility for their decisions. Scientists have lost a lot of their aura in cases like the blood transfusion scandal in France, bovine ESB disease in Europe, AIDS policy in the USA and, most recently, pharmaceutical relief for AIDS in Africa. In environmental catastrophes such as the Ericka or the Exxon Valdez shipwrecks, or even more tragic events, such as the Union Carbide's plant explosion in Bhopal or the Chernobyl nuclear accident, debates have largely focussed on the irresponsibility of the large corporations. But what is new is that scientists and engineers in each of these cases have been involved and, in the long run, their abrogation of responsibility has had a disastrous effect on the whole scientific profession.

Science at the bar has also been used differently. It is now common to have experts not only on the side of the accused but also for the defence. In these instances, as Jasanoff has shown, the boundaries of what constitutes "scientific knowledge" are put to the test.[24]

In some very rare cases, public authorities have tried to give citizens a voice: this was the case in the Berger Inquiry in Canada on the construction of a large gazoduct. Here, lay people challenged a technocratically defined project very efficiently. The investigation of Judge Berger clearly showed that the public's knowledge of their environment may have been much more refined and in-depth than the information used by the relevant scientists.[25]

Large associations of citizens such as the ActUp! AIDS organisations or the Myopathetic Association that launched the Telethon, are actually initiating a new form of participation in the planning and decision-making of scientific programmes. These actions are far beyond simple rejection of science and opposition to specific projects or refusal to accept a given situation should not be viewed as a threat but rather an opportunity to build large proactive movements that are able to raise funds and invest in science.

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[24] Jasanoff, S.S., Contested Boundaries in Policy Relevant Science. *Social Studies of Science*, 1987. 17(2, May): p. 195-230.

[25] The Berger Inquiry (or MacKenzie Valley Pipeline Inquiry) is reported in a book by Sclove, Richard E. (1995). *Democracy and technology.* New York, The Guilford Press, pp.28-29 and pp.48-53.

Appropriate technologies for the Third World has been another enduring movement where consistent effort has been made to involve users of technologies, despite a poor public image and systematic downgrading from technical experts. Many of these efforts have resulted in a better organisation of productive practices and a better adaptation of specific technologies to the social and productive environment. Unfortunately, these efforts have also been accompanied by the paraphernalia --usually generous -- of ideologies, which have robbed them of the attention they merit.[26] Nevertheless, after more than thirty years of persistent efforts, it can be said that much progress has been made.

Grassroots movements, in India, Bangladesh and many African countries, have been the focus of long-term efforts to facilitate more coherent activities between scientists and users.[27] The analysis of the implementation of technologies in the context of poor countries has shown that it is interesting to understand how a technology is evolving jointly with its applications. As in industrialised countries, technologies rely on the social and economic context and the learning that then takes place can be similarly analysed.[28] Work done over the last ten years in the sociology of techniques shows that the design of technology integrates all users of the technology, willingly or otherwise.[29] Any artifact can be said to represent specific interest groups or at least can attribute its uses to specific groups.[30] This has important consequences for the implementation of technologies in developing countries.

In the context of rich countries, these same ideas — along with the need to control the effects of technological development — have led to the idea of "participatory design" for technologies.[31] But this participation in the research design is a problematic, since it not only challenges the traditional ways by which research programmes are done but also the power positions of experts and scientists. Moreover, this participatory design requires specific institutional configurations, which do not currently exist..

III. The ingredients of a renewed S&T policy

Responses to these challenges are not easy, mainly because they concern the roles played by institutions. Not only has the notion of *national* policy-making been challenged but also the very idea that there is the need for a public policy has been put under question. *Public action* has been

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[26] **Of course the most striking example is Schumacher's book *Small is beautiful*. See an interesting reassessment of Schumachers' ideas by Bruce Piasecki in www.loka.org. (Loka Alert November 2001).**

[27] **And not only on technological grounds. The Gramen Bank in Bangladesh is an excellent example of sucess story based on grassroot efforts. A modern analysis of a locally developed technology can be** found in: de Laet, Marianne and Annemarie Mol (2000). "The Zimbabwe Bush Pump: Mechanics of a Fluid Technology." *Social Studies of Science* vol.30(2): 225-263. A Good example of a locally developed technology.

[28] See Sverrisson, Arni (1992). *Innovation as a collective entreprise. A case study of carpenters in Nakuru, Kenya* and from the same author (1990). *Entrepreneurship and industrialisation. A case study of carpenters in Mutare, Zimbabwe*, both reports from Research Policy Institute, University of Lund.

[29] Akrich, M., M. Callon, and B. Latour, A quoi tient le succès des innovations?, in *Gestion **de la recherche***, **D. Vinck, Editor. 1991, De Boeck: Bruxelles. p. 25-76.**

[30] **Bijker, W., T. Hughes, and T. Pinch, eds. *The Social Construction of Technological Systems. New Directions in the Social Study of Technology*. 1987, MIT Press: Cambridge, Mass.**

[31] **Sclove, R.E., *Democracy and technology*. 1995, New York: The Guilford Press. 338. See also Jill Chopyack, Participatory design for science, in the EOLSS Encyclopedia.**

challenged on the grounds that privately funded and privately led research is better oriented toward the innovation system. Moreover, with the advent of knowledge as the foundation of economic value, S&T policy becomes more attuned to aspects that go beyond research: it not only concerned with knowledge creation, but also with its absorption and diffusion. This extension of the scope of S&T policy obliges policy-makers to reconsider the role of research institutions, international relations and organisations and the relations between the public and private sector. It compels them to reconsider the very notion of the "public good".

The theoretical implications of the challenge of "the public good" will not be considered here. (This has been thoroughly examined by Michel Callon in response to the economic analysis of Dasgupta and David.[32]) Here we just want to consider the areas of public policy that are appearing as the beginning of some kind of response to these challenges.

1. The need for S&T policy

It is clear today that the *stricto sensu* definition of S&T policy, as the support and promotion of scientific and technological institutions, is no longer viable. Direct subventions and support to public research institutions need no more justification than the support of national strategic objectives. Support for private enterprises was previously achieved only by virtue of their participation in public activities, like enterprises working as military providers, or supplying public markets. Now that the emphasis has shifted to whole R&D and innovation development in enterprises, the question has been raised of the legitimacy of public support. If the innovation benefits the firm, there does seem to be a reason for the state to fund its activities, even if it engages in some public participation. These policies have thus been accused of "picking the winners" and have been strongly opposed by new liberal governments, as epitomized by the Reagan administration and Thatcher's government in Great Britain. In brief, the debate always has tended to become polarised around the market pole and the public pole. This debate is crucial, since from its outcome will determine whether there will be an S&T policy or an innovation policy.

After the OECD, the World Bank tried to make a point in favour of public intervention in support of knowledge creation, and diffusion.[33] One has to remember that the demonstration of a direct contribution of science and technology to growth has been a long a difficult quest.[34] It has now, however, been demonstrated, and seems to be an accepted fact, that S&T activities participate effectively in growth in important proportions, but in proportions that are nonetheless difficult to measure, an *indirect contribution* of technology to growth. This has been supported by some econometric analysis, although results have been inconclusive as to how much science and technology or education contribute to growth, and by

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[32] **Callon, M., Is Science a Public Good ? *Science, Technology, and Human Values*, 1994. 19(4): p. 395-424. The paper responds partly to the queries of** Dasgupta's and David's claasic paper published in 1994 : "Toward a new economics of science." *Research Policy* 23(5): 487-521.

[33] **World Bank, *Knowledge for development. World development report 1998-1999*. 1999, Washington DC: The World Bank. See also, *La technologie et l'économie. Les relations déterminantes*. TEP Programme technologie/économie, ed. F. Chesnais. 1992, Paris: OCDE (exists in English).**

[34] **Social Sciences, Science Policy Studies, Science Policy-making, *Jean-Jacques Salomon article in EOLSS***

observations of the new industrialised countries, mainly the Asian Tigers (South Korea, Singapore, Taiwan and Hong-Kong).[35]

Apart from the important need for 'catching-up', two main arguments seem to emerge when trying to demonstrate the need for public intervention. The first one relies on "market failures" in the case of the public good, and the second one "positive externalities". Let us briefly decipher this arcane language.

Market failures in terms of economic analysis occur when a market is not adequately allocating resources. There are many possible reasons for this, but it mostly happens when goods are not totally appropriated, that is bought and sold, on a market. It also happens when immediate risks are high and the benefits will only be reaped after a long period of development. Costs of innovation development need to be borne now but profits will only appear much later. In many cases of technological development, there is also a high risk of research programmes not being able to deliver innovations on time. In all these cases, prices are not a good indicator of the value of the public good in question. As a consequence firms tend to under-invest in R&D, technological development and innovation activities even if they know that future profits may be high. If the market fails in delivering then one needs a "visible hand" in order to replace the invisible hand of the market. The state appears then to be the only "hand" that can help investment in risky and costly areas.

The second reason why the state may have to interfere in private concerns involved in S&T activities is because of "positive externalities". The word externalities is usually associated in economics with *negative* externalities, that is costs involved in an economic activity which are the not accounted for by the economic agent who produces the activity. Environmental costs are typical negative externalities. For example, firms do not account for the cost of polluting water sources and the air they use. In contrast, positive externalities are benefits induced by some activity. Innovation and education produce such positive externalities: benefits that go beyond the immediate measurable profits. Innovations enhance aspects of the economic context in such a way that they benefit social groups, or at least some portion of the social and economic world. Modifications to infrastructures, the use of quality control standards or institutional innovations spread such "positive externalities", the benefits of which go far beyond the sole innovators..[36]

These then are arguments in favour of innovation policies and the development of the so-called *"national system of innovation"*.[37] Of course, opponents to the privatisation of science will call in the support of curiosity-oriented science, or science unconnected to profit. But these arguments have not proved effective in defending the position of

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[35]Wade, R., *Governing the market: Economic theory and the role of the government in East Asia industrialization*. 1990, Princeton: Princeton University Press.
Hamilton, G.G., *et al.*, Neither state nor markets. The role of economic organization in Asian development. *International Sociology*, 2000. 15(2): p. 288-305.

[36] As Paul Thompson has shown, costs of a technology are evaluated in relation to a moral and philosophical stance that permits to define standards of Justice and human rights. See article in the Encyclopedia as well as his book : Thompson, P. (1997) *Food Biotechnology in Ethical Perspective* London. And : Burkhardt, J. (1992) Ethics and technical change: The case of BST, *Technology and Society* 14: 221-243.

[37] Lundvall, B.-Å., ed. *National Systems of Innovation. Towards a theory of innovation and interactive learning*. 1992, Pinter Publishers: London.

scientists. Perhaps it would be better and more interesting to explain that markets cannot be used as the sole instruments to measure the value of knowledge, because knowledge is always more diverse than that which the market chooses to use. Moreover, markets also need this diversity to provide them with continuous flow of knowledge and new ideas.

Innovations exert an effect on markets by modifying market conditions and competition. They tend to permit "winning" companies to adopt monopoly positions; they change the nature of markets and the rate of diffusion of innovations: more importantly, they modify the behaviour of actors in the market. Over time, competing technologies are progressively eliminated from the market to the benefit of a small group of companies who then exploit a "dominant design". Something similar happens to R&D; progressively different areas of research are eliminated because they do not fit the dominant design in the market. Governments are called to support innovation in sectors where competitive stakes are high. These are also the sectors that are less diverse technologically. Consequently, the areas from which new technologies could possibly appear become rapidly eliminated, unless there is seed funding available that is not linked to an immediate profit motive.

Traditional economic theory has no adequate intellectual instruments in order to understand these structural effects of innovation on the economy. Innovation strategies are contrary to "business as usual" economic strategies, because innovators seek information differentials. The value of innovation lies in these differences, when a company disposes of a potentially beneficial process or product or a process nobody else has in hand. Equilibrium markets and equally distributed information happens only in a world void of innovation. Knowledge for all is knowledge with no economic value.

This may be called *the basic paradox of innovation policy*. The state supports research and development in order to reduce information gaps; however by promoting innovation it enhances knowledge gaps. Of course this is a very general paradox, and depends on the sector and the technology.[38]

2. Networks, collaboration and competitive research

It is clear that the spectacular growth of research and technology agreements between firms is challenging the traditional frameworks for policy. But also, policy affects strongly these alliances. All policies governing the status of S&T activities in public institutions exert a profound impact on the possible alliances. Since the beginning of the 1980's, European governments as well as the United States have created strong incentives for the development of collaborative activities between the worlds of production and research. Research projects funded under the European research programmes have been actively promoting these collaborations and we are witnessing the creation of large networks that unite research activities, productive activities and the market. These are usually international networks and have a transnational range of action; they associate entities from different countries and also receive support from financial sources in different countries or in transnational or international entities.

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[38] It should be mentionned that the knowledge we talk about here is knowledge that can be circulated independently from its producer: medicines, objects, equipment, norms, even advice that is commercialised all under such a definition. Knowledge systems, per se, do not fit such an argument.

These networks, promoted by policy frameworks, such as the Technology Transfer Act in the USA (1986) or the European Union S&T Frameworks (1984, date of the first Framework) have grown intensely. Whether they are formally designed, as is the case of legally constituted research consortiums or in groupings that have been designed for the development of a temporary research project, they are becoming the common way of carrying out research, but may differ widely in nature, composition and scope.

While networks are essential for innovation, and thus are a strong tool for innovation development, research networks also simultaneously provide space for more diversified research. This is due to the fact that they by nature combine the more applied, innovation-oriented work, with the more basic. This means that the problem is partly one of finding the right partners and not merely locating the right research agenda. In any case, policy-making in S&T has to include a form of management of these networks that transcends the boundaries of traditional institutions.

The network approach is interesting because it is not obliged to think of a whole innovation or S&T system. It permits one to be pragmatic and does not require a defense on the excessively hard ground of principles. However, scientific activities carried out as loosely interconnected activities under strong and diverse external influence, require that the partners involved are flexible, open and at the same time resilient to external threat. Similarly one also needs to be responsive to external demands, be they justified or not, whether of an economic nature or otherwise. The management of complex techno-economic networks thus appears to be a matter of distributing roles and managing scientific resources.[39]

3. Infrastructure in the knowledge economy

The increasing use of information and communications technologies has affected the everyday life of institutions and research groups in ways we still haven't entirely understood. This fundamental change has been labelled as the arrival of a new economy. Neither the financial or commercial dimensions of the phenomenon, with which the word "new economy" has been usually associated, are new. What is new is the creation of a new *infrastructure,* a set-up which is embodied in the Internet, the World Wide Web and all sorts of communication protocols. An infrastructure pervades all aspects of production and communication and thus its setting up is important. Normativity on transfer protocols is usually seen as a too highly technical area, but in fact it models the whole production and management of technologies. It should thus be an area of public policy making and not just a matter of discussing norms between stakeholders, as is the case between larger communication firms. In developing countries this issue is crucial because the information gap is even larger than the prevailing technology gap..[40] The state has to act directly on these invisible infrastructures so that local companies get the benefits of information flows that go through these channels.

In this regard research will be probably affected more deeply than other social and economic activities by this new infrastructure. Scientist in

[39] **We presented this argument in 1986:** Arvanitis, Rigas, Michel Callon and Bruno Latour (1986). *Evaluation des politiques publiques de la recherche et de la technologie. Analyse des programmes nationaux de la recherche.* Paris, La Documentation Française.

[40] See the World Banks report of 1999 title *Knowledge for development* Washington DC, The World Bank, 252 p.

universities and research centres, companies and public institutions rely heavily on electronic communication (like e-mail). Maybe we will see the emergence of new *collaborative research practices*. With the advent of worldwide digital communication, it is possible to imagine managing a large-scale scientific project only through electronic collaborations. Although this might seem to be an unrealistic goal, today all global projects include real collaborators working in far away places. A lot more is needed in order to promote this ideal. But it clearly appears that budgeting and management techniques will have to be modified. Also, new tools will be devised as the computational power increases and the costs of computing and communication fall.

Publication practices will also be profoundly modified. Publication is still based on the idea that individuals produce individual articles. In many research areas, papers are never individual papers, and sometimes authors do not seen the final version before publication. Moreover, the huge publishing conglomerates that manage the publication of scientific journals have difficulty in providing information at the pace rapid pace needed by researchers. The advent of electronic publishing will probably thus profoundly modify the publication process.

Finally the new communications means could be used for long-distance teaching (virtual classes are already set-up) and permit far-away locations to be fully integrated into the educational system.

As G. Bowker puts it: "The science and technology policy in the context of the new knowledge economy needs a deep understanding of the nature of information infrastructures. It means policy makers monitor the standards and classification systems that are getting layered into our models and instruments that we use in perceiving reality. Also, policy making will have to take into account the necessary changes of our institutions so that they can take maximum advantage of the new collaborative and information-sharing possibilities. Some of the issues at stake for science and technology policy are the development of flexible, stable data standards; the generation of protocols (both social, in the form of international agreements about data exchange, and technical, in the sense of metadata standards) for data sharing; and the restructuring of scientific careers so that the building of very large scale scientific infrastructures is as attractive a route as the performance of high profile theoretical work"[41].

4. Program evaluation and technology assessment play a pivotal role

Evaluation plays a key role in S&T policy.[42] The discussion generally concentrates on the criteria and procedures for evaluation at the individual level, which concerns researchers, particularly in the academic and the public sector. Evaluation is an important event in their careers since it is through this mechanism that they obtain the recognition for their work by their peers. Researchers' evaluation is thus an *ex-post* process, which relies heavily on the institutional organisation of the disciplines. It concerns the career and the recruitment of young researchers. As a consequence, people working in research domains with less clearly defined disciplinary boundaries (as is always the case in more original research) usually have more trouble getting reliable evaluations of their work.

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[41] G. Bowker, *The New Knowledge Economy and Science and Technology Policy* in the EOLSS Encyclopedia.

[42] Of all aspects of policy-making, evluation is the most important. The EOLSS has three contributions on evaluation on this by Rémi Barré, Muñoz et al, and Russell and Rousseau.

Evaluation of projects is another matter and it is becoming more and more important, since most research is now funded via calls for tenders. This *ex-ante evaluation* of projects is a filter that permits the guidance of the instrumentation of a policy. The choices of evaluators, the criteria and terms of reference for the evaluation, the relations between evaluators and programme officers, and the calendars of the evaluation can all influence the quality and impact of the programme. Here again, evaluation plays a pivotal rule.

However, the evaluation of research programmes is another matter, much newer and complex.[43] Here, a programme — composed of many projects— is examined in for its implementation, the follow-up and its results. The exercise comprises techniques to evaluate technical aspects — the use of indicators and surveys — as well as the political aspects. Most of these evaluations are *ex-post*, but some effort is now made to give research programmes the means to carry out a *process evaluation* as well.

Finally, a whole new area of development has been created under the name of "technology assessment", a term that has been in favour since the 1960s. Without going into the detail of these methods and rationales that support TA, let us just remember that TA has a duel purpose: it forecasts the impacts of technological development and provides feedback into the policy processes. TA as a form of *public service* has had its days of glory with the Office of Technology Assessment in the USA that was finally disbanded, not surprisingly, by a strongly conservative Republican congress. It developed a large array of studies and methods that are still in use. Other parliamentary and governmental bodies have been modelled on the OTA, like for instance the *Office d'évaluation des choix scientifiques et techniques* of the French parliament. It is important to underline that more and more effort is being made to provide private actors with the necessary tools to participate in the assessment process, and thus transform it into a more participative arena instead of just an exercise in expert advice and stakeholders discussion. Technology assessment, at least in the form of "constructive" technology assessment[44], is a means of responding to the demand for more active citizen participation (but surely not the only manner, as there are many ways the public can participate).

From looking at all these different types of evaluation, it is clear that evaluation plays a *strategic role*. Programme evaluation is becoming a pivotal moment in policy-making. It is one of the rare moments in policy-making where one can see the multiple influences that act upon a research programme. A research programme is always subject to the influence and pressure of individual choices, institutional arrangements, theoretical choices, and political choices. Programme evaluation reveals these influences. It also plays a signalling or alerting role. Understanding the consequences of a research programme or a technology is always difficult. "Prospective", technology assessment or technological forecasting and programme evaluation use similar techniques (scenarios, cost-benefit analysis, expert advice gathering and the like) but there is, however, a fundamental difference that makes evaluation really strategic. Programme evaluation generates its own information and modifies the areas of intervention, whereas technological forecasting uses external information

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[43] A good overview of the issues is: Callon, M., P. Larédo, and P. Mustar, eds. *La gestion stratégique de la recherche et de la technologie. L'évaluation des programmes*. Col. Innovation, ed. P. Mustar. 1995, Economica: Paris. Also available in English.

[44] Rip, A., T.J. Misa, and T. Schott, *Technology in Society: The approach of constructive technology assessment*. 1995, London: Pinter.

and acts only as a confrontation of opinions. A programme actively modifies the conditions of the markets, the technologies, and organisations. This active role explains why there has been a real lack of evaluation for programmes promoting information technologies: by the time evaluation is done, the organisation has changed sufficiently so that everyone is then committed to it.

On a more general note, there is a tendency to open-up the democratic debate on the effects of innovation, and science and technology. Technical change, as Paul Thompson argues, changes the rules of the game in the same way as a change in law or policy. "Yet typically technological innovators escape the purview of procedural rules that govern changes in law or policy [...]. The problem is not that technology fails to be beneficial, but that there is no forum in which society as a whole can weigh the merits of a technical change [...] and then make a decision to accept or reject it. It is the missing forum for deliberating over the change in our social rules that will be made by a given technology that is the basis for a concern with procedural justice."[45]

5. International level: redefinition and the need for a regional perspective

It seems that, paradoxically, globalisation has increased the importance and role of governments. As we have already mentioned, international competition and cross-border alliances can be promoted actively by the policy regimes. A possible response to globalisation might be the adoption of a regional perspective, the promotion of regionally based S&T policy tools and the promotion of international collaboration, even with users of technologies. Policy at the regional level might concern[46]:

- **Networking (virtually, as well as physically) of existing research centres in areas of national/strategic importance;**
- **Support to regionally designed innovation alliances between firms, as well as between firms and research centres;**
- **Common and harmonised laws concerning property rights, as well as common contractual obligations and rights;**
- **Common infrastructure, with shared standards, common systems of scientific and technical references;**
- **A common approach to the needs and means of financing research facilities and information exchange on issues that are trans-boundary in nature (e.g.: environment, transport, and career mobility).**
- **A common system for the evaluation and implementation of policies, including common indicators for S&T;**
- **Promotion of similar career patterns for researchers, mobility of students and scientists, and introduction of regionally focused scientific studies programmes and scholarships;**
- **Promotion of common social and ethical values in scientific and technological matters, and in the dissemination of sound scientific advice through consultative bodies;**

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[45] Paul T. Thompson, *Justice, Human Rights and Ethics Issues in Science and Technology Policy,* article in the EOLSS Encyclopedia.
[46] Adapted from Paul Dufour *S&T Policy in the North-American entity,* article in EOLSS.

- **Organisation of political debates at a regional level on the design of research initiatives, innovation policy and more generally debates that permit the participation of citizens from different countries.**

The European Union has tried to figure out the means for creating such a regional research space.[47] The three North American countries in the framework of the North American Foreign Trade Agreement (NAFTA) have intentions to design the first steps for such a construction. The Asia-Pacific ventures in cooperative science and technology have been experimenting with possible instruments that could bring countries of the region together. African countries, for quite different reasons, are taking steps towards the possibility of common initiatives based on similar experiences in the evolution of their S&T. Undoubtedly, globalisation and these evolutions mentioned above, tend to create favourable conditions for such trans-boundary meetings.

Another important international level of action is that of trans-boundary intellectual rights. With the advent of the global negotiations on world commerce in the World Trade Organization, patenting and intellectual property issues are becoming main issues. The TRIPS (Trade related intellectual property rights) agreement at the WTO lays the foundation of a global minimal set of standards for all types of intellectual property: copyrights, trademarks, service marks, industrial design, geographical indications, patents, layouts, designs for integrated circuits and trade secrets. Although there is very little empirical evidence supporting the arguments in favour of the strict observation of intellectual property rights, the increasing role of private companies promotes a tighter regulatory frame for IPRs. How will this affect the amount and importance of research needs still to be understood. Moreover, action against the kind of negotiations that created the TRIPS agreement is becoming more intense and is connected to efficient anti-WTO activism. For example, in the cases of expensive medicines for AIDS and other innovations property of transnational firms to whom patenting rights belong, protest against excessively high protection has also been significantly supported by poorer countries..[48]

Finally, we would like to mention that a new area of international action has been the setting-up of international cooperation agreements that concern high-level training (PhD) linked to research. These agreements, promoting international collaboration, have been actively supported by researchers in the developing countries who see this as an opportunity to formally obtain support from foreign governments for their students, in an attempt to stop the "brain-drain".[49] Some countries have even created programmes that seek to induce a "brain-gain" by profiting from the researchers who are working outside their frontiers (as has been the case in Colombia and South Africa).[50] Rich countries see these training programmes as opportunities of linking the developing countries to their own technologies and research more closely; little is known of the real

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[47] See Regina Gusmao *The European S&T policy*, in EOLSS.

[48] Quéau, P., A qui appartiennent les connaissances? *Le Monde Diplomatique*, janvier 2000.

[49] Science and Technology Policies in the Context of International Scientific Migrations, *Anne-Marie Gaillard & Jacques Gaillard (IRD, France)* article in the EOLSS Encyclopedia. Also: Gaillard A.M. and J. Gaillard (1999). *Les enjeux des migrations scientifiques, internationales: de la quête du savoir à la circulation des compétences.* Paris: l'Harmattan.

[50] Meyer J-B., J. Charum, et al. (1997). Turning Brain Drain into Brain Gain: The Colombian Experience of the Diaspora Option. *Science, Technology & Society*. 2(2), 285-315.

impact of these programmes, which may lack visibility and are usually promoted on a limited scale.[51]

IV. Conclusion: Towards a more democratic debate on science

We tried here to present some of the issues at stake, posed by the change of the context of research in a pragmatic way. We also reflected on how S&T policy management affects us and which ways it is being undertaken. To be pragmatic does not mean to be inactive. And new reflexivity does not mean insensibility. We cannot just reject the movement toward the privatisation of research by defending old institutional positions that will be disbanded sooner or later. The threats to researchers need to be better understood. It is no use imagining the bad capitalists on one side and the good guys in the public sector on the other, a caricature that does not correspond with reality. Institutions define orientations and budgets, but also need and define dreams and reality, desires and rules. We still live with the "*imaginaire*" (in French) of an industrial and centralised civilization, born out of statism. Up to now most mobilization against privatisation has been in defense of direct interests: salaries, job positions and living conditions. This defense was effective until the advent of larger corporations, tentacular markets and the incredible connection of the virtual financial markets and real activity. We now need to face the profusion of institutions created on an international level. It is important to remember that the people who create institutions work with a given amount of information and have a limited range of action. Once created, institutions reclaim space. The best defence for research now seems to create public arenas of discussion, to promote the democratic debates on research agendas and technological impacts, to promote the expansion of private contradictory research programmes. This would then provide a stimulus for institutions that are more open, flexible, and transparent.

[51] But see R. Arvanitis and H. Vessuri. Scientific cooperation between France and Venezuela in catalysis. International Social Science Journal, 167. Forthcoming.

ANNEX : Table of contents of section

1.30 SCIENCE AND TECHNOLOGY POLICY

Encyclopedia of Life Supporting Systems (EOLSS) —to be published, end of 2001

A section edited by *R. Arvanitis (IRD)*

1.30.3.3. Management of technology. ***Roberto López-Martínez (UNAM, Mexico).***

1.30.3.4. Strategic alliances in S&T. ***Nicholas Vonortas (George Washington University).***

1.30.3.5 The new knowledge economy. ***Geoff Bowker (UCSD, USA).***

1.30.3.6. The economics of innovation. ***Corinne Tanguy (ENESAD, France).***

1.30.4. The policy making process in Science and Technology

1.30.4.1. Policy making processes and evaluation tools: S&T indicators. ***Rémi Barré (OST Paris).***

1.30.4.2. Evaluation of scientific activities. ***Emilio Muñoz, Juan Espinosa de los Monteros, Víctor M. Díaz (U. Politicas Comparadas, Spain).***

1.30.4.3. Technology assessment. ***Arie Rip (U Twente, Netherlands).***

1.30.4.4. Bibliometrics and institutional evaluation. ***Jane Russell (UNAM, Mexico) & Ronald Rousseau (Belgium.)***

1.30.5. Regional perspectives: A new scenario for Science and Technology Policies in the developed and developing world

1.30.5.1. **Perspectives for S&T policy in Africa.** ***Roland Waast (IRD, France).***

1.30.5.2. South-East Asia.

1.30.5.3. Changing S&T policy cultures in India. ***V.V. Krishna (JNU, India).***

1.30.5.4. S&T policy evolution China. ***Gu Shulin (UNU Maastricht and Qinghua University, China).***

1.30.5.5. S&T policy in Latin America. ***Alma Rocha–Lackiz and Roberto E. Lopez–Martinez (UNAM, Mexico).***

1.30.5.6. The European S&T Policy, ***Regina Gusmao (OST, Paris).***

1.30.5.7. **The North American entity.** ***Paul Dufour (Industry Canada.)***

1.30.5.8. S&T policy in Japan. ***Yukiko Fukasaku & Sachiko Ishizaka.***

1.30.5.9. Changing innovation system of economies in transition. ***A. Inzelt (IKU, Hungary) and T.Balogh (Min of education, Hungary).***

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