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Elements of the Public Policy of Science, Technology and Innovation

LES ÉLÉMENTS DE LA POLITIQUE PUBLIQUE DE LA SCIENCE, DE LA TECHNOLOGIE ET DE L' INNOVATION

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Abstract: This work analyzes the structure, elements and formulation of science, technology and innovation policy, providing examples of countries on distinct continents. The authors show that the following elements can be used as the basis for analysis of national cases: institutions, legal framework, science policy agents, plans, programs, resources and assessment instruments.
Key words: Science and technology policy; innovation; research and development; science policy agents; legal framework of science policy

Résumé: Cet article analyse la structure, les éléments et la formulation de la politique de la science, de la technologie et de l'innovation, en fournissant des exemples des pays dans de différents continents. Les auteurs montrent que les éléments suivants peuvent être utilisés comme des bases d'analyse des cas nationaux: les institutions, le cadre juridique, les agents de la politique de science, les plans, les programmes, les ressources et les instruments d'évaluation.
Mots-clés: politique de la science et de la technologie; innovation; recherche et développement; agents de la politique de la scientifique; cadre juridique de la politique de la science

We see that knowledge, quite literally, makes the difference between poverty and wealth. (Kuznetsov & Dahlman, 2008, p. 6).

1. INTRODUCTION

Scholars have long been interested in the problematic of social studies of science. As a result of this interest, there is a tendency among academics to believe that concern about science and technology activities has become a priority for governments, especially in the most industrialized countries like the U.S., Japan,

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Germany, France and so forth. Some scholars point out, for example, that the U.S. won World War II thanks to the strategic investment in science and technology manifested in the Manhattan Project.

However, scholars are not the only parties interested in the social dimensions of science. On the contrary, we can argue that for at least the past century, science and technology have been central to popular and especially political considerations and strategies, as demonstrated by precedent such as the public and widely followed debate between M. Polanyi and J. D. Bernal in the 1930s. Polanyi was a defender of the autonomy of science and the self-government of the scientific community, desiring that science participate in a lasting way in the resolution of social problems and needs. In turn, Bernal, under the influence of Marxist thinking, favored a science in the service of social and political needs, with government and civil society participating directly in the debate over science programs and their agendas. In 1939, Bernal advocated greater State investment in science and technology, after ascertaining that the United Kingdom dedicated only 0.1 percent of its GDP to research and development (R&D), and the U.S. and the USSR only 0.6 and 0.8 percent respectively (Brooks, 1996, p.15).

During World War II, this debate repeated itself in the U.S., with different names but the same basic concern: the future of science in national life. On the one hand, Vannevar Bush, as exemplified in his 1945 report *Science: The Endless Frontier*, defended a position similar to that of Polanyi. He saw universities as the institutions par excellence to embody the autonomy of science research and, as a consequence, its effects on the country's socio-economic sphere (Zachary, 1997). On the other hand, Senator Harley Martin Kilgore supported a posture similar to that of Bernal, stressing the need for government to play a prominent role in the development of the science research agenda (Brooks, 1996, p. 16). In light of the evolution of the problematic of science in political spheres, marked by the Cold War and the arms race, we might ask who, between Bush and Kilgore, was right. However, more than answering this question, what interests us here are the debate aroused and the role to be played by science activity in boosting or strengthening the socio-economic and political development of a country.

Although there is much to be said about the strategic function of scientific knowledge in the framework of an information- and knowledge-based economy,[3] for our purposes it is enough to acknowledge that in contemporary society, knowledge, especially scientific knowledge, has become the primary source of wellbeing and wealth in the majority of the most developed countries. In other words, in contemporary society, specifically post–World War II, science is no longer, as in Plato's republic, of a purely contemplative nature, an end in itself, but rather a requirement for innovation; in turn, innovation is a decisive instrument for promoting and fostering social and economic development (Pulido and Fontela, 2005, p. 5).[4] This perspective allows us to understand the formal establishment of science and technology public policies and institutions, including ministries or secretaries of state and different ad hoc councils, in many present-day countries. Considering that policy and public administration should go hand in hand, we will examine the different elements that give structure to public policies of science, technology and innovation. In so doing, we hope to provide points of reference which can be used in analyzing national cases. These elements are: science policy institutions; legal framework; plans and programs focused on the development of science and technology activities; availability of human, material and financial resources; and a formal system for assessing science and technology activities.

2. WHAT IS SCIENCE AND TECHNOLOGY PUBLIC POLICY?

2.1 Science Policy

The field known as Science, Technology and Society has its origins as a scientific discipline in the 1960s. Among the field's lines of research is *science policy*, which boasts an abundant literature and comprises

[3] "We are living in a time characterized by the rise of the information society in its diverse reality. The foundation of this society is informationalism, which means that the defining activities in all realms of human practice are based on information technology, organized (globally) in information networks, and centered on information (symbol) processing." (Castells and Humanen, 2002, p. 1)

[4] Further on, the authors distinguish between the "innovation triangle," which is formed by science, society and economy, from the "knowledge triangle," which is formed by education, research and innovation. (Pulido and Fontela, 2005, p. 15)

countless theories and finely wrought contributions. Drawing on this foundation, we will employ the definition of science policy proposed by A. Nadal. According to Nadal (2005), science policy can be defined as a set of measures, decisions, interventions or activities realized by a determined society's distinct political powers, with the main and ultimate objective of favoring, stimulating or inhibiting the progress of research, as well as employing the results of this research in products with socioeconomic, political, cultural or military ends (p. 95). S. E. Cozzens (2003), in turn, understands science policy as government actions affecting the role of technology in the everyday life (p. 55). J. Sebastián (2007), analyzing this subject, adopts a similar approach, highlighting the fact that science policy is a "collection of strategies and instruments that permit the promotion of scientific and technical research in order to achieve objectives, which range from the production of the most relevant knowledge possible to its application in technological developments that can further socio-economic progress and improve the quality of life of citizens"[5] (p. 626). Perhaps the most important point to highlight from these definitions is that the aims of science are not restricted to the generation of knowledge but also include objectives of economic and social nature, which places science and technology activities in the public arena as never before in history.

It is worth pointing out that there is no way to guarantee immediate benefits when undertaking scientific research, as evidenced by the existence of market failures.[6] According to J. A. Peña and L. Archundia (2005), markets failures necessitate State, or better said government, intervention in scientific research and technological development. Also, State intervention is manifested, for example, in policies favoring subsidies or incentives meant to achieve optimal development of science and technology. The term *public policy* appears in this context, understood as a collection of actions concerning problems to be tackled by government functionaries.

One of the principal characteristics of modern government policy, in whatever area it is applied, is the negotiation of the concerns of different interest groups, acknowledging collective participation in public problems. Accordingly, science policy recognizes collective participation in science and technology activities. Businesses have become leading players in R & D, beyond the increased protection from which they might benefit in the context of a government policy. Civil society has also become involved in debating science and technology policy, in light of the consequences of science and technology for civilian value systems. Responsibility for scientific matters is now shared, at least in principle, between the government, the private and academic sectors and civil society. This approach encompasses H. Etzkowitz's triple helix[7] and adds in civil society, which the former perspective does not explicitly contemplate (Casas, 2003). Modern science policy, as public policy, is essentially characterized by the integration of diverse points of view and a plurality of approaches and interests: "the public policy agenda now tends to be collectively defined by government organisms, political representatives, social and business groups, and on occasion also by direct citizen participation" (Cabrero, Valdés and López, 2006, p. 4).

2.2 The Agents of Science Policy

From the previous section, we can deduce that science policy is a means by which contemporary State governments seek to obtain the most benefit from science and technology activities, as well as a collection of actions involving diverse actors. It chiefly concerns the producers of knowledge (scientists), the productive or industrial sector, political power as regulator and party responsible for outreach (the government), and civil society. In order to examine the types of relationships that exist between these actors,

[5] All translations are ours unless otherwise specified.

[6] Drawing on J. Schumpeter's conception of tough competitive markets in which only the most dynamic and creative businesses, capable of producing new products and processes, survive, Peña and Archundia (2006, p. 134) show that generating new knowledge is the duty of the social and private sectors. However, the interrelation between the private and social sectors is not sufficient for the optimal developed and science and technology, given the economic idiosyncrasies that the authors call "market failures," which make government intervention necessary. In order to justify this intervention, government demonstrates that knowledge is "non-appropriable," that is, its benefits cannot be totally appropriated by the whoever realizes the investment, which means that there are insufficient incentives for private production of knowledge, for example in the case of basic science. Also, where benefits could exist, they might not be manifested for a long period of time.

[7] This approach had been developed previously by J. Sabato in the 1970s, under the name "triangle of development." (Casas, 2003)

we will employ the distinction used by Rubio (2005) when he speaks of social subjects and fields, following P. Bourdieu: given that the agents involved in science and technology activities are diverse, one can infer that the interests pursued by different groups are also dissimilar. Here, Rubio (2005) demonstrates that the concept of a *field* is a notion that permits us to approach science as a social phenomenon that involves different scenarios, subjects and socially constructed places and times: "Social fields are the spaces in which a society's members can interact and negotiate. Interaction can arise when two or more individuals establish communication in the code of the context in play" (p. 116).

In the framework of a social field, the concept of *interaction* implies a dialectic relationship between the different parties involved. This interaction takes place in terms of a normative code that links parties together, but does not eliminate contradictions or conflicts due to the interests in play. Finally, the relationships between the forces present determine the normative codes between different fields, but so do formal rules that facilitate communication or interaction as to the science and technology activities that we consider in this paper.

If the concept of the social field evokes a space where interaction takes place, concrete historical subjects interact in the social field in order to negotiate or communicate. On this matter, Rubio (2005) says:

> When individuals group together according to some indentifying criterion, they form a type of social agent not identifiable by the list of its individual members, but rather by the characteristics of a social identity. Each such group constitutes a social subject, and each has a recognizable social identity and a capacity for communication with the rest of society because of this identity. (p. 117)

Given the concepts of social fields and social subjects, we can deduce that there are four fields of analysis related to science and technology activities: the scientific field, the educational field, the productive field and the political field. The scientific field, which exists to produce knowledge, is defined by assessing the validity of its findings and their membership in the body of scientific knowledge, and is associated with the scientific community. In other words, the scientific field is a space where the contents of scientific production are discussed and evaluated. This space includes the university classroom, laboratories, congresses and specialized colloquiums, thesis presentations, academic journals, scientific publishing companies, assessment committees and so forth. (Rubio, 2005, p. 118). Social negotiation occurs in the scientific field when determining research subjects, projects and agendas, as well as in publications, and in the problematic of financing, or how to obtain resources from the State and other social institutions related in one way or another to science activities.

The objective of the educational field is to negotiate the structure of the formal system of knowledge reproduction. The principal social subjects in this field are educational institutions and the State. There is a close relationship between the scientific and educational fields, given that the educational system is mostly responsible for the formation of human resources, including future researchers. Also, we know empirically that the majority of researchers and research centers collaborate, in one way or another, with institutions of higher education (Rubio, 2005, pp. 120-121).

The productive field is an agent or subject in charge of satisfying the material and service needs of a society, which means that economic dynamics are front and center. In capitalist societies, businesses, especially those belonging to the private sector, are the main actors in this aspect of socio-economic life. Given the importance of the production, distribution and consumption of goods and services, it follows that the State is one of the main interlocutors in the productive sector, as the government is in charge of regulating the conditions in which the productive system must operate. Institutions of higher education also participate in the productive field in situations concerning research oriented towards technological innovation, given that the productive field can incorporate technology into its activities via innovation or technology adoption (Rubio, 2005, p. 125).

The political field is a space for a society's public negotiations. Rubio (2005) argues that public discussion of scientific matters has become more important in most developed economies in recent decades, especially since World War II. The concept of *State policy* emerges in this context. This concept is based on the recognition of the strategic character of science and technology activities beyond the political platforms of government functionaries in office. The creation of state entities in charge of political science planning—for example ministries or secretaries of State and national or federal agencies—is justified on this basis. These entities are intended to regulate or foment the aspects of nation life where technology seems to be indispensable for the sustenance and development of the society's structure. The science and technology plans or programs proposed by the different governments of modern States in the frameworks of their economic and socio-cultural policies are rationalized a posteriori according to the same logic:

> The State must negotiate the allocation of resources for scientific research with the scientific community. It must negotiate fundamentally the same question with educational institutions; in another historical moment it had to negotiate the scientific contents of education. With industry, the State must negotiate the politics of technology modernization. With the NGOs, it must negotiate environmental policy. As a meta-subject, the State is present in some degree in every social system […]. (Rubio, 2005, p. 129)

In this way, different fields and social subjects share some theoretical characteristics, while concrete contexts and actors are determined by a specific country's history and the dynamics that characterize science and technology activities in that country. The State appears mainly as a force that organizes and binds the different forces or fields relating to science policy, given their unique attributes.

2.3 Science Policy versus Technology Policy

As stipulated in the methodology handbook known as the Frascati Manual,[8] the Organisation for Economic Co-operation and Development (OECD) understands science as complex, systematic research comprised of three branches: pure or basic research, applied research and technological development (Godin, 2005, p. 19). In keeping with this conception of scientific research, when we speak of science policy throughout this work we understand science in this triple dimension. For example, we will see that in the U.S. an increase in productive and innovative capacity simultaneously promotes scientific research and technological development, which demonstrates that there is a dialectic relationship between the production of knowledge and the demands of an knowledge-based economy oriented towards national and international productivity and competitiveness.

As per this perspective, there is no point in distinguishing between science policy and technology policy. However, we can provide examples of countries that make this distinction, such as Finland, where the Ministry of Education assumes responsibility of the country's science policy via the Academy of Finland, with its primary focus on the pure research realized by institutions of higher education, while the Ministry of Employment and the Economy, through the Finnish Funding Agency for Technology and Innovation (Tekes), is in charge of technology policy realized by institutions of higher education and industry.

Nevertheless, if we agree with the linear way of thinking about scientific research proposed by Vannevar Bush, who conceived of technological development as a mediate or immediate consequence of pure research, then we must conclude that the concept of science policy already encompasses technology. It is this linear view that M. J. Santos and R. Diaz (2003, p. 359) call "the conception of human progress," in which scientific development is understood as leading to technological development, which in turn brings about to economic development through production of goods and services; and economic development causes social development, which, closing the circle, supplies resources for scientific development. According to L. Sfez (2005, p. 66), however, in modern society scientific progress goes hand in hand with technical advances, as opposed to the former inevitably preceding the latter. Additionally, it would be illusory to maintain that technical or technological advances are necessarily applied in inventions, stricto sensu. In fact, not only is history full of technical advances independent of previous scientific developments, but science itself has become dependent on technics or technology, which lead C. F. von Weizsäcker (1966) to compare science and technology to trees with different roots but intertwined and interconnected trunks and branches. Moreover, invention in itself is currently not particularly consequential, and innovation alone has a very short lifespan. In virtue of the interdependence between science and technology, Sfez (2005, p. 68) coins the concept of innovention, taking for granted the primacy of technoscience as the new way of conceiving of the interdependence between science and technology in the contemporary context, defined by mass use of information and knowledge.

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[8] The first edition of the *Frascati Manual* was published in 1963 under the direction of C. Freeman. It has been revised periodically since.

For purposes of this paper, we will assume that science policy implies technology policy, which in turn implies and supports science policy. In short, we prefer to speak of a dialectic relationship between science policy and technology policy, which presuppose and sustain each other. In fact, L. Bach and M. Matt (2005, p. 18) adopt the express position of not distinguishing between science policy and technology policy, because science policy, technology policy and innovation policy are based on the same principles. We draw on this perspective to understand the institutional structure of science and technology activities, as well as investment in R&D. Given this dialectic, in this work we will not distinguish between science policy and technology policy, knowing that speaking of one implies speaking of the other without assuming, strictly speaking, its identity.

2.4 Science Policy as State Policy

When speaking of a State policy pertaining to science and technology, one is actually in a profound sense rescuing the very assumptions of modernity. In effect, if knowledge is power, as Francis Bacon affirmed at the beginning of modernity, today we know that this statement applies to not only the cultural but also the political and economic dimensions of power. In the contemporary context, characterized as the *information society* or *knowledge society*, scientific and technological knowledge are recognized not only as a catalyst for R&D, but science itself is also considered to be the center of economic dynamics. The modern State, as we will see, has made scientific research and technological development one of its preferred tools in the pursuit of public welfare. The fact that national and international contexts are, in macroeconomic terms, defined by competition remains implicit in the modern State's quest for general welfare. From here stems the permanent struggle to provide the capacity necessary for innovation and competitiveness.

With regards to this matter, for our present purposes it suffices to mention Schumpeter's idea on the subject Peña and Archundia (2005, p. 134): the innovation capacity of countries and business has become the key or sine qua non for economic survival at the national and international levels. If businesses are, in short, one of the main users of both scientific and technological knowledge, this implies that there is a national innovation system capable of creating and adapting knowledge. Concretely, universities, public and private research centers, laboratories and so forth are necessary for science and technology activities, and all of these institutions require general and statutory laws, and consequently sufficient political power, in order to function.

Also, science policy has crossed over from being an anticyclical policy to become a State policy. Historically speaking, the U.S. case can serve as an example. The mobilization of resources for the Manhattan Project is an essential milestone in the history of science and the inauguration of Big Science as a characteristic par excellence of the twentieth century. As a result, the U.S. is considered to be the first country to implement mass investment in R&D in the post–World War II years, exceeding the total sum of investments in R&D by the other OECD countries. The key factor in this investment is the link between academia, industry and the federal government (Mowery and Rosenberg, 1993). Big Science has even taken on a symbolic social meaning. In 1961, Alvin Weinberg, the first director of Oak Ridge National Laboratory, observed that

> [w]hen history looks at the 20th century, she will see science and technology as its theme; she will find in the monuments of Big Science—the huge rockets, the high-energy accelerators, the high-flux research reactors—symbols of our time just as surely as she finds in Notre Dame a symbol of the Middle Ages. She might even see analogies between our motivations for building these tools of giant science and the motivations of the church builders and the pyramid builders. We build our monuments in the name of scientific truth, they built theirs in the name of religious truth; we use our Big Science to add to our country's prestige, they used their churches for their cities' prestige; we build to placate what ex-President Eisenhower suggested could become a dominant scientific caste, they built to please the priests of Isis and Osiris. (p. 161)

As we can see, Weinberg establishes an analogy between the eagerness to construct the instruments of Big Science in the twentieth century and the eagerness to build churches and pyramids in other historical moments, creating monuments that indicate what was considered prestigious in their respective ages.

Following E. Pesquero and G. Muñoz-Alonso (1997, p. 172), we suggest that, by factual contingency, it follows that developed countries have science policies not only to take advantage of their natural and human resources, but also in order to remain productive and competitive by satisfying present and future technological needs. To illustrate, large government science policy institutions were also created in the twentieth century, including the U.S. National Science Foundation (NSF) in 1950, the South Korean Ministry of Science and Technology[9] in1967, the science and technology councils established in almost every Latin American country in the 1970s, and so forth.

Because science policy is now a matter of State, the most industrialized countries currently tend to invest about two to four percent of their GDP in this area.[10] Public investment is generally in strategic sectors that benefit the general population, such as defense, health and transportation, while industry tends to invest in sectors that are expected to be profitable in the short, medium or long term. R&D expenditure is led by the public sector in some countries and the private sector in others. In developed countries, more often than not the private sector focuses on applied research and technological development, while the public sector finances mainly pure research. The U.S., France, Germany, Finland, South Korea, Taiwan, Singapore and Japan are some of the countries where the private sector invests more in applied research and technological development than in pure research.

Also, we could say that science and technology policy, as State policy, is both bottom-up and top-down—the dual functions of the State. In other words, the different levels of government have the authority and legitimacy to regulate what one may and may not do in the area of science and technology, and at the same time they are obligated to receive the suggestions, proposals, requests and recommendations of concerned citizens and others. Said yet another way, science and technology policy is open to societal deliberation: the State, through the government, takes the initiative to develop science and technology via diverse strategies; but the State itself also receives proposals from the public, private and social sectors meant to strengthen, correct or prevent the collateral effects of the application of science in everyday life.

3. SCIENCE POLICY INSTITUTIONS

According to L. Corona (2002, pp. 260-261), the concept of an *institution* can be understood as the establishment of limits meant to structure human interaction, which goes hand in hand with the idea of restrictions, both formal and informal. On the other hand, G. Burdeau (1968, p. 583) maintains that an institution is a business at the service of an idea and has at its disposal much more power and duration than the individuals that act in its name. Combining the elements of these two definitions, we can understand by institution an organization defined by limits, rules and norms affecting social interaction, and that disposes of an identity of its own prerogative and works for the realization of an idea. Following Corona (2002), we also point out that an institution is defined by limits conceived of by humans so as to structure their actions. In this context, we understand by the concept of *limit* a group of formal and informal restrictions in a process where the protagonists of the negotiation want to minimize risk as much as possible. This definition contains the elements that are indispensible when discussing *science policy institutions*. Science policy institutions are organizations governed by a normative framework; they exist in order to strengthen their founding idea, and they are shaped by values defended or shared by the members of the organization or society at large.

In continuing with this analysis, we will employ the tripartite division made by R. Oliver (2006) between *decision-making institutions*[11] (political actors), *bridge institutions* (intermediaries) and *scientific research and technology development institutions* (implementers). In Oliver's perspective,

[9] In 2008, this ministry was combined with another ministry and is now the Ministry of Education, Science and Technology.

[10] According to the OECD (2006), in 2003 the U.S. dedicated 2.7 percent of its GDP to spending in this area, while other countries dedicated similar parts of their GDPs, for example: 4.5 percent in Israel, 2.5 percent in Germany, 1.8 in the U.K., 4.0 percent in Sweden, 3.5 percent in Finland, 2.0 percent in Canada, 3.2 percent in Japan and 2.9 percent in Korea (p. 18).

[11] Bearing in mind that all institutions can and in fact do make decisions, in this work with will discuss *strategic* decision-making institutions and not just decision-making institutions.

decision-making institutions are responsible, politically speaking, for designing plans and programs for the implementation of science policy at a national level. Bridge institutions are organizations that embody the rules or restrictions related to science policy. They play the part of mediators between decision-making institutions and the institutions that execute science policy decisions. These include institutions of higher education, public research institutions, science and technology NGOs, industry, foundations and so forth. Science policy attains its dual function by way of bridge institutions: top-down, from political actors to implementers; and bottom-up, from implementers to political actors.

3.1 Strategic Decision-Making Institutions

Depending on the country, different ministries or secretaries of State embody public authority and are invested with the power to make decisions concerning science and technology. For example, in Finland, the Ministry of Education makes decisions regarding science policy, while the Ministry of Employment and the Economy makes decisions concerning technology policy. Meanwhile, in South Korea the Ministry of Education, Science and Technology, headed by the country's vice–prime minister, has made decisions on science and technology policy since 2008.[12] To the extent that ministries or secretaries of State, that is to say government, make science and technology policy decisions, it is worth emphasizing that making a decision means affirming authority (Freund, 1981). In other words, the State, through the government, makes strategic decisions, pronounces the priorities that it establishes, and at the same time mobilizes the means necessary for turning its political will or societal project into a reality.

In the decision-making government, groups commonly called *councils*, composed of public functionaries and other expert advisers, are necessary in order to ensure effective decisions. The formation of councils is a way of escaping from decisionism—voluntaristic, unrealistic and dangerous—, which results when facts and expert opinion on complex topics, such science and technology policy, are overlooked in decision-making. In the context of the modern State, councils are established bodies composed of figures from the political, academic, business and special-interest sectors. Their mission is to advise government functionaries and advocate measures suggested by their expertise. In other words, these bodies are in charge of acting as spaces for reflection, orientation and recommendation with respect to activities that require more than will or demagoguery. They are authorities on determining what, when and how to act, but they do not directly dispose of the popular legitimacy or constitutional mandate to speak, and much less to act, in the name of the people. As a consequence of these unique functions and restrictions, the very efficiency of science and technology governance is at stake in determining the criteria governing the actions of councils.

As part of the institutional structure of the modern State, in a way these councils operate under stricter bureaucratic norms than those officially mandated (Weil, 1981). They interact with academic institutions as well as businesses, receiving pressure and demands from both. With this in mind, a better way to understand these councils would be as bodies of experts that formulate strategic visions for science policy in modern States. Also, they tend to work on two fronts. On the one hand, they prepare strategic proposals or visions of science and technology policy. On the other, they promote and coordinate research; this in so far as they define strategic projects, establishing the state of the art, and, ideally, advise politicians to make sensible, informed and opportune decisions.

Many scholars in the field of Science, Technology and Society, among others Casas and Albornoz, recognize that on an international level, the creation of science policy institutions denominated *science and technology councils* began in the 1950s. Albornoz (2001, p. 59) defines these councils as organs central to science policy, responsible for allocating resources for science activities, as well as for representing the scientific community and forming part of a system of autoregulation. According to A. Rip (1994), we can understand these councils "hesitating between a 'parliament of scientists and a government bureaucracy' " (p. 3). Albornoz (2001, p. 65) adds that councils perform the following functions: formulation of science policy proposals, elaboration of science and technology development plans, surveying of the area's potential and recourses, resource financing and management, coordination of research activities, coordination of external technical assistance, and training in and creation of science and technology information services. Thus, councils set the ground for making decisions, which leads to believe that

[12] Between 2004 and 2008, when it merged with the Ministry of Education and Human Resources Development, the Ministry of Science and Technology made science and technology policy decisions.

decision-making institutions are bodies invested with the political authority to determine broad science policy guidelines, design development plans, strategically orient the actions of different actors, sanction those who do or do not fulfill follow through on agreement, evaluate results, and take retroactive measures necessitated by current work plans and programs.

We can illustrate the concept of the decision-making institution with reference to practice in Finland. In effect, Finland is a country with a relatively limited number of actors in its national science and technology system: the Parliament and the State Council are the political institutions that decide the course that, in general, policy should take in the country. However, in practice, the Science and Technology Policy Council is the entity that proposes guidelines regarding science and technology and formulates general recommendations directed to government and the scientific community, especially where policy is concerned. The members of said Council are the Prime Minister, who acts as its president; the Minister of Education and the Minister of Commerce and Industry, who are vice-presidents; other ministers; and representatives of funding agencies, research institutions and labor organizations. Every three years, the Council publishes a report on the state of science and technology in the country and the strategies to follow in the future (Hakala, 2003, p. 192).

3.2 Bridge Institutions

If highest-level decision-making is the duty of political authorities, there are also agencies that are responsible for serving as a bridge between political authorities and R&D institutions. Accordingly, when instrumentalizing or executing science and technology decisions is a prerogative of the political authorities, bridge institutions assume these responsibilities. Thus, in accordance with an area’s functions and legal framework, the responsibility to create, manage and coordinate research environments—such as university or industrial laboratories, studio offices, institutions responsible for science or technology research and so forth, including research personnel and funding sources —is or could be incumbent on the secretaries of State and agencies that function as bridge institutions.

The NSF in the U.S. is an example of a bridge institution. The NSF is an independent federal agency created in 1950 by Congressional decree in order to “promote the progress of science; to advance the national health, prosperity and welfare; [and] to secure the national defense” (NSF, n.d., “NSF at a Glance”). The NSF defines itself as an agency whose duty is to realize national studies and questionnaires, currently following the methodology established by the OECD, in order to determine funding for science and technology activities in the Federal budget (Hill, 2006, p. 4). Also, the NSF is the only Federal agency to finance all areas of pure science and engineering, with the exception of medical sciences,[13] including high-risk research and projects that might seem like science fiction but show promise. Its mission is to ensure that the U.S. continues to occupy a leadership role in scientific discovery and development of new technologies. With an annual budget of approximately six billion dollars, the NSF contributes about twenty percent of the funding for pure research awarded by the Federal government to institutions of higher education. In areas like mathematics, informatics and social sciences, the NSF is the largest financing agency. Every year, the agency finances about 200,000 scientists, engineers, professors and students committed to science and technology work in institutions of higher education and laboratories in the U.S. and throughout the world. The fact that over 187 beneficiaries of NSF financing have won the Nobel Prize, not mention many other prestigious awards, speaks for itself (NSF, n.d.).

In general terms, a similar description could also apply, mutatis mutandis, to the National Science and Technology Council in the U.S.,14 Sitra in Finland, the Academy of Finland, or the National Council of Science and Technology in Mexico. Still, it is worth mentioning that the each agency realizes different activities according to its institutional design and the legal framework concerning science policy in the country where it operates. To illustrate this point, we recall that in Finland, the Academy of Finland is responsible for pure science activities in the country’s institutions of higher education, while Tekes is the agency responsible for activities related to technological development, working closely with industry and

[13] In the U.S., the National Institutes of Health fulfills this function.
[14] The NSTC was established by the U.S. Federal Executive Branch on November 23, 1993, as the main organ by which the President would be involved in coordinating U.S. public policy dealing with science, technology and space. Thus, the NSTC coordinates many Federal R&D programs.

also with institutions of higher education doing research in the field. Also in Finland, Sitra is responsible for financing R&D in areas that are strategic for the future of the country.

3.3 Research and Development Institutions

The principal institutions involved in scientific research and technological development are institutions of higher education, public and private research centers, and public and private laboratories. These R&D institutions are frequently dependant on the three main categories of supervisory institutions: government, businesses and universities. Government supports many institutions devoted to scientific research and technological development. In Mexico, for instance, there are a variety of different public research centers dependent on the National Council of Science and Technology, such as the Center for Research and Teaching in Economics, the Center for Research and Higher Education in Social Anthropology and so forth. At the same time, various scientific research and technological development institutions are dependent on businesses or the productive sector. This category primarily includes the different laboratories dedicated to applied research or technological development, like those that helped South Korea to become globally competitive in the 1980s. We can also name numerous institutes and research centers dependent on universities; the National Autonomous University of Mexico alone hosts more than thirty research institutes (Universidad Nacional Autónoma de México, n.d.). Thus, while the university plays its part, scholars in the area of science policy increasingly recognize that the university is not the only actor in the production of knowledge.

In the most developed countries, the capacity for knowledge production creates a favorable environment for the emergence of knowledge industries. In countries like the U.S., the government appears to finance a large part of pure research, but the private sector is the main source of financing for applied research and technological development. For instance, in 2002, the private sector provided sixty-six percent of investment in R&D, the Federal government funded twenty-eight percent, and the remaining six percent came from institutes of higher education, local governments and science and technology NGOs (Hill, 2006, p. 8). Mutatis mutandis, we can observe the same basic pattern in South Korea, Japan, Germany and Finland, that is, the preponderance of the private sector in applied research and technological development, while government and institutions of higher education focus on pure research. For example, there are scores of centers of excellence in South Korea, including science research centers, engineering research centers and regional research centers. At the same time, South Korea also maintains government-supported research institutes. First created in the 1970s, these institutes specialize in a specific area, such as naval construction, earth sciences, electronics, telecommunications, energy, machinery, chemistry and so forth (Ministry of Education, Science and Technology, n.d.).

4. SCIENCE POLICY INSTRUMENTS

If in the previous section we have highlighted the institutional structure of science policy, we must recognize that we still lack an explanation for how public policies concerning science, technology and innovation are operationalized. Although institutions appear to be the most important social instruments to this end, we are interested here in underlining the mechanisms utilized by institutions in order to realize activities or negotiations related to science and technology activities. In order to enter into this part of our discussion, we will examine the legal framework of and plans and programs concerning science and technology, as well as the assessment of science and technology activities.

4.1 Legal Framework of Science Policy

It happens that the majority of industrialized and developing countries have, in addition to their constitutions, general and statutory laws that govern science and technology public policy. We can understand this in the context of the modern State, which E. Weil (1984) defines as a constitutional State or a State of law, especially considering the transcendence of science in social and economic life. The importance of antitrust policy in ensuring the efficiency of the U.S. innovation system speaks for itself in understanding the makeup of science policy tools (Mowery and Rosenberg, 1993, p. 32).[15]

[15] We refer to the Sherman Antitrust Act passed at the end of the nineteenth century.

Thus, science policy is governed by law. To illustrate our affirmations, we can point to South Korea's Constitution, which stipulates that "(1) The State strives to improve the national economy by developing science and technology, information and human resources, and encouraging innovation. (2) The State establishes a system of national standards. (3) The President may establish advisory organizations necessary to achieve the purpose referred to in Paragraph (1)" (HUNBUP [SOUTH KOREAN CONST.] art. 127). From this article we can see that in South Korea the job of realizing science policy corresponds to the President of the Republic, in collaboration of course with other ministers and specialized agencies. That the director of the Ministry of Education, Science and Technology reports to the Prime Minister does not contradict constitutional decree, because the Prime Minister reports to the President of the Republic. Moreover, in addition to having a group of expert science advisors16 at his disposal, the President of the Republic is the President of the National Science and Technology Council, which serves as the control tower for the country's science and technology activities, in accordance with the 1997 Special Law for Scientific and Technological Innovation.

Science policy regulation has taken a different course in the U.S, the global leader in magnitude of investment in R&D.[17] The U.S. Constitution does not explicitly establish science policy guidelines. In fact, there is no mention of science and technology outside of a clause stipulating that the Congress has the power to "promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries" (U.S. Const. art. I, *§ 8, cl. 8*). But if the U.S. Constitution says little about the legal framework of science policy, we must also immediately recognize the abundance of acts and decrees that regulate this area. A recent example, submitted and passed in 2007, is the America COMPETES Act, which has precedents in diverse proposals, such as the reports *Rising above the Gathering Storm* (2007) by the National Academies and *Innovate America* (2005) by the Council on Competitiveness. The America COMPETES Act emphasizes three focus areas in order to maintain and improve innovative capacity on the U.S. in the twenty-first century: 1) increase investment in R&D; 2) strengthen educational opportunities in the areas of science, technology, engineering and mathematics, beginning in primary school; and 3) developing the country's innovation infrastructure.

According to A. Berrueco and D. Márquez (2006), science and technology norms taken as a whole constitute the legal framework of science policy in Mexico. Some of the most important regulations include articles 3 and 73 of the Federal Constitution, the Science and Technology Act of June 5th, 2002, the Organic Act of the National Council of Science and Technology,18 the Organic Statute of the National Council of Science and Technology, the Science and Technology Special Program and the Operational Rules for National Council of Science and Technology Programs.

With these illustrative cases, what we want to underline here is that science and technology public policy is supported by legal norms. A country's constitution, general laws, regulations and decrees provide the basis for interaction between different institutions, and the different internal regulations or organic laws guide the operation of these institutions. Thanks to diverse norms or laws, the State provides a structure that directs R&D activities in order to achieve higher levels of productivity and competitiveness in the national economy. However, in order to attain this productivity and/or competitiveness, one of the instruments par excellence is the different science and technology plans and programs.

4.2 Science and Technology Plans and Programs

The distinction between plans and programs essentially has to do with the type of objective(s) that they pursue, and not so much the time that they dedicate to those objectives.[19] Speaking in terms of science and technology, a plan establishes the general guidelines for the implementation and continuation of science

[16] We refer to the Presidential Council of Advisors on Science and Technology.
[17] According to the OECD (2006), in 2004 U.S. investment represented almost 43 percent of total investment in R&D by OECD member countries (p. 18). The leadership of the U.S. in absolute terms is due to the size of its economy, and knowing this we can infer that the U.S. is still leader in this area.
[18] The Science and Technology Act and the **Organic Act of the National Council of Science and Technology** were approved by both the House of Representatives and the Senate, on April 24, 2002, by the former and on April 30 of the same year by the latter. They were published in Federal Register on June 5, 2002.
[19] South Korea's R&D nuclear program was contemplated, from its launch in June 1992, for 10 years.

and technology policy as well as the concrete strategies necessary in order to achieve objectives. Programs, on the other hand, are actually processes or different steps in the execution of plans, and they are characterized by a pragmatic focus (Schindler, 2004, p. 43). In order to illustrate the distinction between plans and programs, we can use the example of South Korea's "Vision 2025." In 1999, South Korea set the goal of becoming one of the seven most industrialized countries in the world in terms of science and technology development by 2025. In order to realize this plan, different programs were to be implemented in different areas, each generally for a five-year period. Considering the former, we can deduce that the concept of a *science and technology policy plan* includes long- and medium-term general objectives assigned to public projects on the subject of science and technology, while programs are the means for achieving concrete or specific objectives in the short term (Schindler, 2004, p. 39). Programs involving applied research and technology development tend to have concrete and well-defined objectives, while programs involving pure research tend not to have such clear objectives.

When speaking of socioeconomic development in a world that has become a "global village," we cannot lose track of the pressures of international competition, which obligate countries to try to innovate and, of course, invest in R&D (Warnier, 2004). In fact, all OECD member countries currently have national plans or programs regarding dealing with policy. To illustrate the importance of science policy in the management of socioeconomic issues in modern States, Table 1 indicates some recent plans and programs of selected OECD member states.

Table 1: OECD member state plans and policies

Country	National plan	Period covered	Main objectives
Australia	Backing Australian Science and Innovation	2004 –2010	"Strengthen [Australia's] ability to generate ideas and undertake research, accelerating the commercial application of ideas, and developing and retaining Australian skills" ("Backing Australian Science and Innovation for the Future," 2001, cover page)
Finland	Strategic Centres for Science, Technology and Innovation	2007 –2011	Foster innovation and renew the innovation system, stimulate industry and commerce, strengthen R&D processes and increase investment and output through public-private partnerships (Tekes, n.d.)
Mexico	Special Science and Technology Program	2001 –2006	Develop a national science and technology policy, increase the country's technological capacity, and increase business competitiveness (Consejo Nacional de Ciencia y Tecnología, 2001)
South Korea	Revised Science and Technology Basic Plan	2003 –2007	Increase innovation capacity, develop the knowledge society, systematize regional innovation systems, improve R&D infrastructure, increase role of science and technology in industry and society and foster science and technology culture (Yim, 2007, p. 156)
U.S.	American Competitiveness Initiative	2006 – present	Increase innovation and competitiveness by strengthening education in math, science and foreign languages (U.S. Department of Education, n.d.)

It would be premature to conclude that a country's prosperity depends on the implementation of these plans or programs. However, we can stress a characteristic common to all of these socioeconomic development plans and programs, indicative of their effectiveness: they are based on efforts undertaken at least 40 years ago, mainly from 1960 to 1970, such as those mentioned earlier in this paper. Over time, each of the countries mentioned here has learned its strengths and weaknesses and used this knowledge to focus new plans and programs, in the search for the most efficient way to take the greatest advantage of its different opportunities and overcome the challenges of an ever more competitive world.

An important factor in understanding these programs is Big Science, a concept that has resonated since World War II and the Manhattan Project. Big Science projects reunite different actors—such as scientists, engineers, administrators, politicians and industrialists—according to their size, reach and economic cost. Basing themselves on de Solla Price,[20] Pesquero and Muñoz-Alonso (1997) maintain that far from being

[20] See de Solla Price, 1963, *Little Science, Big Science*. The main idea of this book is that the history of science can be divided in two parts: that of Little Science and that of Big Science. Presently, in contrast with previous epochs, science mobilizes greater resources thanks to the institutions at its service: many countries have Ministries of Science and Technology, while this type of institution did not exist in previous periods.

the exception confined to World War II and the U.S., Big Science projects are currently a common practice in the majority of industrialized countries. The science policies listed in Table 1 corroborate this.

According to Pesquero and Muñoz-Alonso (1997, p. 172), R&D programs must take different factors into account. These include science research, technology design, political decisions and assessment activities (previous assessment of feasibility and suitability, a posteriori evaluation of efficiency and impact or consequences). What is implicit here is that R&D programs must meet social and economic development objectives, which means that the most important parameters for evaluating projects are social needs and priorities, as well as science and technology resources.[21] Once all of these elements have been taken into account, the government can proceed with the execution or implementation of the program. In other words, government can proceed with revising the initial objectives or simply abandon the program if it is not feasible.

At the same time, it is worth noting that science and technology programs in different countries do not share the same profile. In the U.S., for example, Mowery and Rosenberg (1993, p. 30) emphasize the fragmentary nature of program financing and administration, as both the Federal Executive branch and the Congress share initiatives. In Finland, in contrast, Tekes and Sitra take the lead in public financing of and investment in R&D. In South Korea, as typical in East Asia, R&D program development is strongly centralized. Here, the Ministry of Education, Science and Technology, which holds the vice-presidency of the National Science and Technology Council, is the most influential observatory and actor in determining R&D financing.

In spite of procedural differences between programs by country, science and technology plans and programs are commonly seen as strategic elements in addressing how to reach both general and narrow objectives. Plans and programs also resolve the problematic of investment in R&D, as well as, according to J. R. Cela (2005, p. 153), control and follow-up mechanisms, among other things. In a management infrastructure, measuring the percentage of the GDP set aside for R&D expenses, allocating funds to different fields, developing research priorities and so forth, all appear to be inevitable requirements of science planning (Albornoz, 2007, p. 55).

Plans and programs are both instrumental in nature, despite their differences. Science and technology plans represent a country's general goals, while programs are a concrete way of converting these goals into results. Thus, plans have a general, panoramic, indicative, prescriptive and synthetic character, while programs have a more specific, descriptive and analytic character. Plans and programs perform a prescriptive role insofar as they establish a calendarization of the activities and available and unavailable resources in the framework of institutional legality; they fulfill a descriptive role, in that they shed light on the relationships between individual efforts in compliance with programs, specifying what is expected of different participants in the project; and they realize an administrative role, namely, they establish balance in the coordination of activities within the program, highlighting the advances made in their execution.

4.3 Human, Material and Financial Resources

M. A. Quintanilla (2007, p. 185) maintains that science policies are frequently only an issue until Election Day, at which point they are forgotten. This happens in spite of recognition of the importance of scientific knowledge as the motor of technological innovation, and as such of wellbeing and wealth in what is currently known as the information and knowledge society. Science policies transcend campaign statements by means of working programs that depend on human, material and financial resources in order to realize objectives and carry out programs.

4.3.1 Human Resources

If the U.S. is currently the most competitive country in the world, a key to its success has to do with both the quantity and the quality of human resources devoted to science research and technology development. We can see this in quantitative terms in Table 2.

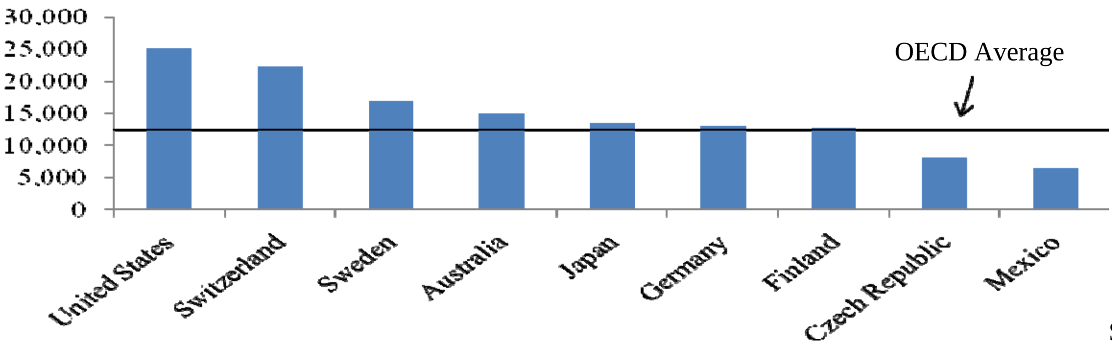
[21] They are not the only parameters because of the belief in the legitimacy of pure research, the main objective of which being knowledge for knowledge's sake. This reminds us of Merton's posture on the autonomy of science research, based on universalism, communalism, disinterest, and organized skepticism, and Michael Polanyi's republic of science. (Albornoz, 2007, p. 54)

Table 2: Researchers by sector (full-time equivalent)

	% by sector			Total number of Researchers	Average annual growth rates
	Business enterprise	Government	Higher Education		
EU-25[a]	47.3	14.5	36.0	1,084,726	3.7[c]
U.S.[b]	80.5	3.8	14.7	1,261,227	4.3[d]

Source: Adapted from European Commission Directorate-General for Research, 2003, p. 45.
[a]Year: 2000. [b]Year: 1999. [c]Years: 1996-2000. [d]Years: 1996-1999.

Table 2 shows three relevant details: first, in 1999, the U.S. disposed of more researchers than the European Union did in the following year. Second, in the same period, the vast majority of researchers in the U.S. worked for companies (80.5 percent), while in the E.U. the percentage of researchers employed by businesses was only 47.3 percent. Third, in the last years of the twentieth century both the U.S. and the EU experienced average annual growth in the human resources dedicated to research of about four percent, although growth was somewhat higher in the U.S. Based on this information, we can conclude that high-level human resources play an indispensable part in the socioeconomic life of the most developed countries. As such, states find themselves obligated to invest in the formation of human resources, as illustrated in Figure 1.



Source: Adapted from OECD, 2009, p. 202.

Figure 1: Annual expenditure of selected OECD countries on educational institutions per student at the tertiary level (2006, in equivalent US dollars converted using PPPs for GDP, based on full-time equivalents)

The relationship between education and science policy is generally very strong. For example, in Finland, the Ministry of Education is in charge of the country's science policy; the Ministry's director is the Vice-President of the Science and Technology Policy Council. On the subject, J. Hakala (2003) says: "The Ministry of Education […] makes performance agreements with all universities every three years and channels other (basic research) funding through the Academy of Finland" (p. 192). Therefore, education appears to be a process that prepares students to make decisions concerning social problematics such as work, environmental pollution, the environment, the common good, security and so forth. Perhaps this is the right place to recall the conclusions of a Royal Society report concerning science education: a better public understanding of science might be the most important factor in increasing national prosperity (Levinson and Thomas, 1997, p. 2).

4.3.2 Material and Financial Resources

Pesquero and Muñoz-Alonso (1997, p. 173) argue that a competitive economy demands that the State facilitate the innovation process in high-demand areas, instead of directing it. Thus, science development plan budgets include basic science and technology expenses. These budgets establish priorities, set human resource requirements and contemplate project evaluation in terms of scientific and technological productivity.

To illustrate the indispensable character of material resources, we point out that carrying out science and technology research requires infrastructure, such as buildings and laboratories, specific inputs required for experimental research, and so forth. Also, it is worth recalling here that if responding to industry's demands is not science's only end, it is still beyond a doubt that the public authority's opinion of investment in R&D has an essentially pragmatic and utilitarian focus: to use the production process to serve society's interests, and to help the productive sector to be more competitive on the national and international levels. J. Hakala (2003, p. 193) maintains that Finland has become a knowledge society thanks in part to its increased investment in R&D.[22]

In the majority of industrialized countries, the productive sector is the largest investor in R&D. In 2003, total investment in R&D accounted for 3.4 percent of Finland's GDP, which made it the OECD member state with the largest percent of GDP dedicated to R&D. Of this expense, the industrial sector financed 71 percent of R&D, while the public sector funded 21 percent. It is worth noting that Nokia is the company with the greatest weight in private investment in R&D, contributing 20 percent of Finland's total investment in R&D (Hakala, 2003, p. 191). As to the public sector, Table 3 demonstrates the main sources of public funding for R&D.

Table 3: Main [Finland] Ministries' R&D funds (2002 plan)

	Funding in millions of Euros	**% of all R&D funds**	**Change from 2000**
Ministry of Education	582	42%	5
Ministry of Trade and Industry	492	35%	-0.3
Ministry of Social Affairs and Health	121	9%	4
Ministry of Agriculture and Forestry	97	7%	19
Other ministries	107	8%	-

Source: E. Arnold, P. Boakholt, J. De La Mothe, E. Deiaco, S. McKibbon & P. S. Simmonds, 2007, p. 5.

Passing from the case of Finland to that of the U.S., we point out that investment in R&D has been responsible for about 60 to 70 percent of U.S. economic growth since World War II (Shapira, 2006). In fact, in the postwar years U.S. investment in R&D surpassed that of all other OECD member states combined. Moreover, we emphasize a particular and distinctive fact that in the last four decades has distinguished the U.S. from other industrialized countries: the creation of companies that invest in R&D and commercialize resultant technologies (Mowery and Rosenberg, 1993, p. 29).

4.4 A Formal System of Assessment

The last aspect of science policy that we will address in this paper is the capacity to evaluate current processes, assess new areas of opportunity and improve works in progress. In effect, since the 1960s, organizations such as UNESCO, the OECD, the European Commission and other national and international statistics institutes have made an effort to conduct quantitative studies concerning science and technology policy. A major advance in this direction was the publication in 1963 of the OECD's *Frascati Manual*, with the purpose of developing standards for the collection of science and technology statistics (Godin, 2005). Of course, the first studies concerning the measurement of science and technology activities are much older. In 1873, Alphonse de Candolle published the first quantitative study about science and technology, *Histoire des sciences et des savants depuis deux siècles*. Later, in 1929, Lokta published his study on the productivity of research chemists (Godin, 2003). Eugene Garfield's Citation Index for Science, made public in 1955, has been recognized by Solla Price and Merton as a one of the most transcendental inventions in the statistical study of science and technology activities (as cited in Van Raan, 2004, p. 20). The list of pre-1960s studies goes on, but it seems undeniable that during that last few decades, assessment of science and technology activities has emerged as an increasingly important tool in the pursuit of more efficient investment in science and technology, measured in terms of the qualitative aspects of research as well as the impact of this research on the wellbeing of the national or local population (Hakala, 2003, p. 194). Given that the assessment problematic is closely tied to the topic of indicators, Van Raan (2004, p. 20) contends that indicators, which are quantitative measures, represent the social dimension of science. Accordingly, the continuity of a project tends to be determined by decisions made during evaluation. Such

[22] For further details, see chapter 4.

evaluations assess the quality of work, its impact, and organizational efficiency. As a result, formal assessment policy and resultant feedback foment competitiveness and efficiency in the national research system (Hakala, 2003, p. 194).

5. CONCLUSION

Independent of ideological considerations, science policy is principally a plan of action or a programmatic agenda that takes science and technology to be axes of socio-political change. Local, regional or national command of science and technology provides a significant comparative advantage in the pursuit of national and international competitiveness and, indeed, in the struggle for survival. Given this strategic value of knowledge, the ability to design and implement a favorable policy is indispensable.

The knowledge-based economy requires productive structures that allow for research results to serve as sources of production and innovation of goods and services, thus permitting a country to be competitive on a national as well as international scale. The economies of the richest countries do not depend on natural resources, capital or work alone, but rather also on factors such as the increase and accumulation of useful knowledge and the transformation of this knowledge into goods and services by means of technological innovation. If a country takes its role in the contemporary global economy seriously, it must recognize the strategic importance of science and technology policy in its socioeconomic development plan. The government must provide the society with learning capacities that permit it to adapt to and innovate in areas with initial comparative advantage and also create new areas and sectors (Kuznetsov & Dahlman, 2008).

This paper elaborates the fundamental elements of any comprehensive analysis of concrete science policy cases, facilitating future studies of science policy in the world's diverse countries and regions. In fact, the authors already employ this framework in analyses of different societies in distinct regional and sociocultural contexts. To conclude, we have developed a table that synthesizes the elements necessary in the analysis of science policy in any given country or region.

Table 4: Elements of science policy analysis

Element	Analysis
Science policy agents	Identify the country's principle social agents and their role in the R&D dynamic: academic sector, productive sector, government and civil society
Institutions	Identify the strategic, bridge and R&D institutions; analyze their capacity to structure R&D activities
Legal framework	Identify the place of R&D in the Constitution and national laws; analyze the conditions established with the intention of providing incentives for R&D activities
Plans and programs	Identify the main R&D plans and programs; evaluate the level of definition and objectives; confirm the possibility of measuring results
Investment in R&D	Identify the amount of investment in R&D and its composition, especially in terms of the public and private sectors
Human resources	Obtain information on human resources with the capacity to realize R&D activities; check if there are sufficient human resources to execute R&D plans
Assessment system	Identify the system of indicators utilized by the State; verify its congruence with national R&D plans; review the incentives arise as a result of outcome measurement

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