The changing role of the science and technology policy advisor in a new global context

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1. Introduction

This chapter examines the changing role of professionals engaged in research, advice, policy-making, and management in the field of science, technology, and innovation policies. The processes of knowledge generation and utilization are now fully inserted in all aspects of contemporary life, their transformation is taking place in the context of a fractured global order, and they require deliberate public policy efforts to mobilize them in the service of development objectives.

After a brief review of science and technology policies, this paper offers a description of the main features of the fractured global order, focusing on the knowledge divide or fracture that has emerged in full view during the last four decades. The evolution of Latin American science, technology, and innovation policies during the last six decades will then be used as an example of how the role of the policy advisor has been transformed, before offering some concluding remarks.

2. Science, technology and innovation policies

The modern conception of science and technology policy as we know it emerged shortly after World War II, a few years after the field was outlined in the seminal work by J. D. Bernal, *The social function of science* in 1939 (Bernal, 1967). Government in the industrialized countries began to emphasize the application of science to practical civilian ends, stimulated by the successful way in which it had been deployed for military ends during the war. A 1945 report by Vannevar Bush for the President of the United States, *Science: the endless frontier*, proposed a series of measures to strengthen scientific research and technological development, which would be reinforced by the pressures of the Cold War, the nuclear arms race, and the conquest of space. Similar initiatives were undertaken in Europe and Japan, and even in India, with Primer Minister Nehru's "Science Policy Resolution" approved by Parliament on March 4, 1958.

The roles of science and technology policy advisors, designers and implementers shifted and changed over time, as did the content policies and strategies. In the 1950s and 1960s, "science policy" placed emphasis on promoting scientific research and technological development, and less on the way in which knowledge and technology were utilized in production activities and the provision of services. As governments adopted economic growth as a primary national

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objective, during the 1970s emphasis shifted towards technology and its role in the economy and "science and technology policy" broadened its scope, incorporating issues such as technology transfer, appropriate technologies, and interactions between research institutes and enterprises.

Advances in scientific research and technology development opened vast new fields for economic activity during the 1980s and 1990s (e.g., information and communications technology, biotechnology, nanotechnology, automation), the content of policies expanded to cover "science, technology and innovation", which sought to stimulate innovative behavior and became more closely intertwined with economic social and environment policies.

The range of concerns, approaches and methods of policy advisors expanded and shifted in parallel with the changing content of policies and strategies, as did the activities of policy research institutions, government agencies, and international organizations. For example, in the 1970s, substantive work on policy implementation and the effectiveness of policy instruments complemented the design and formulation of science and technology policies in institutions such as the Science Policy Research Unit at Sussex University, the Organization for Economic Cooperation and Development (OECD), UNESCO, the Organization of American States (OAS), UNCTAD and the Andean Community (Sagasti 1978, 2011). The concept of "national innovation systems" gained ground during the 1990s and 2000s, which expanded and shifted, once again, the set of issues that policy advisors had to deal with, linking them to evolutionary economic theory and focusing on the relations between technological innovation and the policy and incentive ecosystems within which it takes place.

As we move further into the 21st century, with much more fluid and uncertain international global, national, and local contexts, the study of policy making in general —and of science, technology and innovation policies in particular— has begun to pay more attention to the governmental learning process required to adjust policy design and implementation to rapidly changing circumstances. Even though the design of adaptive science and technology planning and policy-making processes has a long history (see, for example, Sagasti, 1971, 1972), recent research has put forward new ideas and concepts that seek to advance the art of policy design and implementation. Swanson *et al.* proposed "seven guidelines for policy-making in an uncertain world" (Swanson and Bhadwal, 2009), Carden (2009) has focused on how research can inform development policy, and Blindenbacher (2010) has proposed the concept of a "learning spiral" to organize learning in government.

A feature common to these approaches is the emphasis they place on an adequate appreciation of the policy-making context, which requires "an integrated approach to thinking about our environment — a practical means for linking comprehensive, contradictory and incomplete information" and "a better understanding of the dynamics of change we must address" (Swanson & Bhadwal, 2009: 27). For this reason, as the content of science, technology, and innovation policies and the concerns it addresses evolve, it is necessary to offer an interpretation of the process of accelerated globalization that has become highly visible during the last decades.

3. *A fractured global order*

As we enter into the 21st century there is an accelerated, segmented and uneven process of globalization presently under way. The worldwide expansion of productive and service activities, the growth of international trade, the diminishing importance of national frontiers, and the intensive exchange of information and knowledge throughout the world, all coexist with the concentration of "global" activities in certain countries, regions, and even neighborhoods, as well as within certain firms and corporations.

The simultaneous integration and exclusion of countries —and of peoples within countries— are two intertwined aspects of the multidimensional processes of globalization and fragmentation under way in our turbulent period of history, a time that is witnessing the emergence of a *fractured global order*. This is an order that is global but not integrated; an order that puts all of us in contact with one another, but simultaneously maintains deep fissures between different groups of countries and between peoples within countries; an order that is benefiting a small percentage of humanity and segregating a large portion of the world's population.

3.1. Structure of the fractured global order

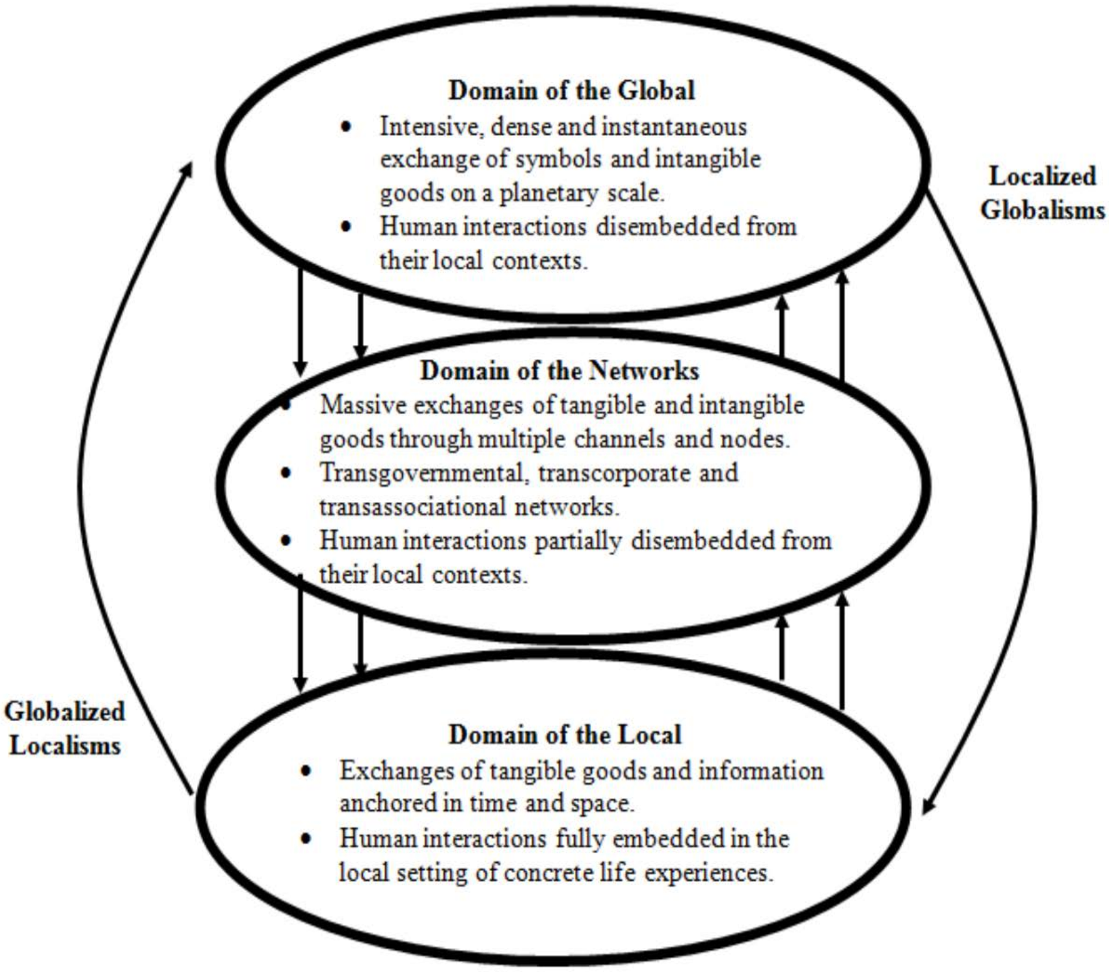
The structure of the fractured global order can be conceptualized in terms of three closely interconnected and partially overlapping domains, each of which has its own specific features and ways of interacting with the other two. These are: the domain of the global, the domain of the networks, and the domain of the local (Figure 1).

The *domain of the global* consists primarily of the intensive, dense, and nearly instantaneous exchanges of symbols and intangible goods on a planetary scale, which are characteristic of the information age. Advances in communications and information technologies have allowed us to free our activities and interactions from the constraints imposed by our immediate and concrete experiences of time and space, and to restructure those activities and interactions almost at will in the abstract domain of the global. The separation and decoupling of time and space from each other, and from their concrete experiential settings, are what make possible the domain of the global. Social relations are thus disembedded or lifted out from their local contexts, transformed into vast and complex symbolic arrays that represent myriad social interactions, and projected into the realm of the global, where they become free to roam and intermingle in a rather fluid fashion.

The *domain of the networks* consists of a bewildering multiplicity of combinations of exchanges of tangible and intangible goods —trade in products and services, power and influence relations, transfers of data and information— which flow through a myriad of identifiable channels and nodes that interconnect social groups all over the world. Interactions in the domain of the networks involve all kinds of organizations —public institutions, private corporations, and civil

FIGURE 1

The Three Domains of the Fractured Global Order



society associations—, whose interrelations create a tangled web of overlapping and intertwined networks of networks. The domain of the networks is constantly transforming itself, as connections between its constituent units are established and severed, new channels and nodes are created and old ones destroyed, and as the network units mutate and evolve.

The social relations reflected in the combinations of tangible and intangible goods exchanged in the domain of the networks are both partially embedded in, and partially disembedded from, the time- and space-bound local contexts of interaction. Long in the making, the domain of the networks owes its present richness to the technological innovations in transport and communications of the last five decades, which have facilitated new and more intensive few-to-many, few-to-few, and few-to-one, as well as one-to-few and many-to-few, patterns of interrelation and communication between human beings.

The *domain of the local* is constituted by those relations and transactions that are anchored in time and space, and which comprise primarily the production, exchange and consumption of tangible goods and services, together with the corresponding information resources and personal interrelations, that are necessary for human beings and social groups to exist and evolve. This domain has been in existence since the dawn of humanity, and the social relations reflected in the transactions and interactions that comprise it are firmly embedded in the settings of our concrete living experiences.

In the domain of the local, where most of our daily lives unfold, transactions are relatively easy to trace and the prevailing patterns of interrelation and communication between human beings one-to-few, few-to-one, and few-to-few exchanges. This domain contains the extraordinarily rich range of face-to-face interactions between individuals that allows us to convey to each other, not only information about things, but also feelings, emotions, aspirations and values, all of which are at the root of what it constitutes to be human, and which confer human beings their unique character.

In economic terms, the domain of the local comprises what are known as non-tradable goods, such as personal services, retailing, local transportation and heavy goods with high transport costs; the domain of the network comprises all types of tradable goods, services, and information that can be transported and exchanged over relatively long distances; and the domain of the global includes what may be called hyper-tradable goods and non-personal services, which can be sold, bought and transferred in a nearly instantaneous fashion all over the world, many of which (currency trading, for example) are exchanged at a frenetic pace.

As these three domains overlap, it is possible to identify social interactions located in the interfaces between them. For example, financial transactions which take place on a global scale, as well as money that never rests but moves constantly throughout the world's financial channels and hubs, straddle the domains of the global and of the network. Point-to-point trade in goods and services taking place through clearly identifiable routes, and which initially requires localized production and ultimately involves localized consumption, spans both the domains of the local and of the networks.

3.2. Features and dimensions of the fractured global order

The emerging fractured global order and its three domains are characterized by a multiplicity of fault lines of political, economic, social, environmental, cultural, scientific, and technological nature; these faults partially overlap and often shift direction; they sometimes reinforce each other and at other times work at cross purposes (Table 1). The overall picture they paint is one of turbulence and uncertainty, in which a variety of contradictory processes open up a wide range of opportunities and threats that defy established habits of thought. Integration and exclusion coexist uneasily side-by-side in all domains and aspects of the fractured global order. All of this is certainly in line with what characterizes periods of profound and fundamental transformations, as was the Renaissance, and as is the transition we are now embarked on, towards a post-Baconian age.[4]

TABLE 1: **Dimensions of the fractured global order**

International Security in a post-bipolar world

- End of the Cold World and demise of East–West rivalry.
- Virtual elimination of the threat of an all-out nuclear war and of conflicts based on Cold War ideology.
- Emergence of new security concerns: environmental conflicts, terrorism, drug traffic, international crime syndicates, proliferation of chemical and biological weapons, proliferation of small nuclear devices.
- Erosion of the political power of nation states (both from below and from above).
- Increase in number and intensity of regional conflicts (ethnic, religious, resource).
- Larger role for international and regional institutions, particularly the United Nations, in maintaining security.

Economic and financial interdependence

- Rapid growth and globalization of financial markets.
- Changes in trade patterns: shift of the content of trade in favor of high-technology services and manufactured products, emergence of the North Pacific as the largest trading area, multiplication of regional trade agreements, growth of intra-firm trade, creation of the World Trade Organization.
- New situations in key countries (United States, Russian Federation, Japan, European Union, China, East Asian newly industrialized countries).

Persistent inequalities and economic uncertainty

- Persistent and growing disparities between industrialized and developing countries.
- Growing inequalities of income and opportunities within both rich and poor countries.
- Greater instability of the international economic system.
- Increasing concern and demands for better international economic governance.

Social conditions

- Demographic imbalances (low growth and aging in rich countries vs. relatively high population growth in developing countries).
- Growing social demands (food, education, health, housing, sanitation) in poor countries.
- Unemployment: developing countries face the challenge of raising labor productivity while absorbing the growing number of entrants to the labor force; developed countries face structural changes in employment patterns and an aging work force.
- Widespread and growing social exclusion (gender, ethnic, age, poverty, education) in both developed and developing countries.

Environmental sustainability

- Impact of climate change in economic and social activities and need to adapt.
- Greater awareness of the problems of resource depletion.

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[4] The transition to the post-Baconian age involves transcending the "Baconian Program" of dominating nature through understanding and the use of the scientific method, which will require major adjustments in the methods, aims, and organization of the scientific and technological enterprise at the global level. For a description see: Sagasti (1997, 2000, 2005).

- Threats to environmental sustainability and appropriate resource-use: poverty in developing countries; wasteful consumption in rich nations.
- Security defined in environmental terms.
- Need for —and development of— environmentally sound technologies
- Acknowledgement of danger posed by global environment problems.

Culture, religion, and ethical concerns
- Growing importance of religious and spiritual values.
- Rise of religious fundamentalism (Islamic, Christian, Hindu, etc.) as a driving force of economic, social, and political actions.
- Conflict between cultural homogeneity and cultural identity as a result of globalization of mass media, communications, and transportation.
- Growing importance of moral and ethical issues in equity and human rights issues.

Governance and spread of democratic practices
- Crisis of governance in high-income and poor nations (e.g. representation vs. efficiency, social demands exceed institutional capabilities).
- Political pluralism, democracy, and popular participation have spread throughout most world regions.
- Rise of "authoritarian" or "illiberal" democracies in several regions.
- Redefinition everywhere of the roles of the public sector, of the private sector, and of civil society organizations.
- Governance problems exacerbated by the social impact of economic policy reforms.
- Information technology having major impact on political systems and governance.
- Growing importance of social capital and of institutional development.

Mass media and communications
- Global spread and growing influence of television (news, opinions, entertainment, images, information) in shaping mindsets.
- Property concentration of mass media and implications for objectivity, diversity, polarization, and balanced transmission of information and views.
- Possibilities of conscious and unconscious manipulation of viewers, listeners, and readers.
- Change of communication patterns: unprecedented possibility for almost instantaneous " many-to-many " communications (Internet, www).
- Potential for interfering in personal communications and related loss of privacy.

Knowledge explosion and knowledge divide
- Exponential growth of knowledge.
- Greater importance of knowledge as a factor of production; emergence of the "knowledge society."
- Changes in the conduct of scientific research: increasing costs, greater specialization, importance of information technology.
- Increasingly systemic character of technological innovation: more and greater diversity of inputs required; more actors involved.
- Change of techno-economic paradigm: from energy intensive (key factor: oil) to information intensive (key factor: microchip).
- Transformation of production and service activities by major advances in communications and information technology, biotechnology and materials technology.
- Extreme and cumulative inequalities in science and technology capabilities between industrialized and developing countries.

- Limited science and technology capacity of developing countries to face economic, social, political, cultural, environmental, and knowledge challenges.

Source: elaborated by the author.

The conceptual framework of the fractured global order does not postulate the existence of an overall coordinator that decides on the course of the contradictory processes of globalization and fragmentation, let alone of a conspiracy to run the world so as to exploit and debase the majority of the world's population that are negatively affected by them. Nobody is "in charge" of the turbulent processes that are creating a few winners and many losers. The various interconnected systems that make up the three domains of the fractured global order run according to their own logic, and those of the interactions between them. This suggests that a first task to confront the threats of the fractured global order, and to take advantage of the possibilities it offers, is to understand the multiple driving forces of its various domains and components, their changing nature, and the logic that animates them.

Nevertheless, the nonexistence of a *deus ex machina* to control the processes leading to the fractured global order does not mean they lack an overall direction. This direction emerges from the prevailing pro-market and anti-state way of thinking in the late 20th century. It is leading, albeit in jagged and paradoxical manner, towards both greater integration and fragmentation in all realms of human activity. Yet, there are significant efforts being made to improve our understanding of the globalization process, and these appear to be gaining ground in the second half of the 21st century as the consequences of the 2007–2009 financial crisis have made it clear that a better balance between market forces and the State has become necessary. In addition, greater policy coordination efforts are being made in a variety of fields. For example, as the growing importance of knowledge is being recognized, there is a drive to spread best practice in science, technology, and innovation policies, particularly by large emerging countries such as China, India, Brazil, and South Africa, smaller middle-income countries such a Chile, and in relatively poorer countries whose economy is growing fast, such as Vietnam.

In the last analysis, perhaps the most important challenge faced by the international community in the transition to the 21st century is to prevent the multiplicity of fractures that span all the domains of the emerging global order from creating self-contained, partially isolated pockets of mutually distrustful peoples, ignorant and suspicious of the viewpoints, aspirations, potentials, and capabilities of each other. It is essential to prevent these fractures from creating inward-looking societies —both between and within rich and poor nations— that relate to one another only through symbolic links forged by mass media or through narrowly circumscribed economic transactions, and that interact in ways that are fraught with conflicts that may threaten human and environmental security.

3.3. The knowledge fracture

The second half of the 20th century witnessed a veritable knowledge explosion as a result of the expansion of scientific and technological research, advances in information and communications technologies, and the greater role that innovation plays in economic growth and business success. Scientific and technological research has long superseded all other forms of generating knowledge, and science-based technologies are the now the main source of innovation in production and service activities. Scientific and technological capabilities have become one of the most important assets in the quest for improving the quality of life and in determining the range of options that countries and regions have to shape their own future.

Because of its intrinsic importance and the fundamental role it plays in configuring the fractured global order and its domains, the knowledge fracture deserves special attention. It is at the root of security, economic, social, environmental, cultural, governance, and communication divides, which in turn amplify the differences in capacities to generate and utilize knowledge, and at the same time is perhaps the most difficult to bridge.

The impact of the knowledge explosion has been felt throughout the planet, but in a most uneven manner. The capacity to generate and utilize scientific and technological knowledge has become highly concentrated in a few developed countries, while the majority of developing countries still rely on traditional knowledge and techniques, complemented by a rather thin layer of modern knowledge, technologies, products, and services, passively received from the technologically advanced countries. The knowledge fracture between those parts of the world where science, technology, and production are tightly intertwined, and those in which the limited scientific, technological, and modern production activities remain apart from each other and where traditional knowledge, techniques, and products still play a major role. The knowledge divide has been relentlessly deepening and enlarging, and has led to a sort of "knowledge apartheid" that radically separates those societies that have an endogenous science and technology base from those that do not (Sagasti 2011, 2004, 2000).

Disparities between science, technology and innovation capabilities of developed and developing countries are much larger than economic disparities. At the end of the 20th century, the ratio between the Gross Domestic Product (GDP) *per capita* of the high-income countries of the Organization for Economic Cooperation and Development (OECD) to that of the low income countries (as defined by the World Bank) was about 70 to 1, while the ratios of gross capital formation *per capita* and trade *per capita* were 53 to 1 and 77 to 1, respectively.

However striking these disparities may be, they are dwarfed by the differences between developed and developing countries in their capacities to generate scientific knowledge, develop modern technologies, and to produce high-technology goods and services. The ratio of scientific publications per 100,000 inhabitants in OECD countries to that of low-income countries is 2,505 to 1, the ratio between patent applications by residents per 100,000 inhabitants is 2,223 to 1, while those of high technology exports *per capita* is 8,009 to 1 (Table 2).

Moreover, scientific research and technological development organizations in most developing countries are highly vulnerable to changes in the domestic economic and political climate, and also vulnerable to the attraction exerted by better-financed and more advanced research and development organizations in developed countries. Building a world-class research institution takes at least a decade-and-a-half of sustained efforts, but these achievements can be destroyed in a couple of years by the emigration of highly-qualified staff.

TABLE 2: **Economic Disparities and the Knowledge Divide**
(2007 or most recent year)

Indicator	***Values and ratios***		
	(A) OECD countries	(B) Low -income countries	Ratio (A)/(B)
Gross domestic product *per capita* (constant 2000 US$)	24,645.6	351.7	70.0
Gross capital formation *per capita* (constant 2000 US$)	4,577.6	87.1	52.5
Trade *per capita* (imports + exports of goods and services) (constant 2000 US$)	13,286.5	171.8	77.3
Scientific output: Scientific publications per 100,000 inhabitants	501	0.2	***2,505.0***
Technological Output: Patent applications by residents per 100,000 inhabitants	66.7	0.03	***2,223.3***
Production Output: High-technology exports *per capita*	961.1	0.1	***8,009.2***

Source: *World Bank Global Indicators*. (Low-income countries, as defined by the World Bank, have an average income *per capita* of less than US$1,005 in 2010.
Note: the full value for technological output in low-income countries (column B) is 0.030558, and for production output 0.121954. Rounding up these figures to two decimals generate the ratios in the last column.

These figures provide a partial snapshot of the huge disparities in the worldwide distribution of science and technology capabilities, and of access to information at the end of the 20th century. However, the asymmetries are much greater than these figures would suggest, primarily because of the cumulative character of the processes of building capabilities in modern science, technology and production. As capacities in these fields are acquired, it becomes easier to continue accumulating them, and those countries that have a long history of doing so are in a much better position to reap the benefit of future advances in science and technology.

This indicates that the science and technology capabilities of most developing countries are far too limited to deal adequately with the challenges they face in the fractured global order of the 21st century. In many cases, they also lack the capacity to effectively select, absorb, adapt, and use imported knowledge and technologies, and for identifying and selectively upgrading traditional knowledge and techniques. Severe resource constraints and growing social demands force the leaders of developing country to make difficult decisions between alleviating poverty in the short term and building capacities to generate and utilize knowledge in the medium- and long term —which would later help to reduce poverty to a much larger extent.

This underscores the importance of adequate policy and strategy design, and the role that policy advisors play in assisting poor countries to build their own science, technology, and innovation capacities. Facing resource scarcities and a dearth of highly qualified researchers and professionals, most developing countries need to deploy limited resources in a strategic manner, and to take advantage of any opportunity that may emerge. International organizations such as UNESCO, which has developed a platform to exchange information on science and technology policies, and the OECD, which has been active in reviewing innovation policies in several developing countries, provide examples of what can be done to improve policy design and implementation in this field.

4. *Knowledge and innovation in Latin America*

The emergence of the knowledge fracture poses a serious challenge for Latin America, which has been trying to build science and technology capabilities for more than half a century. Studies of the interactions between science, technology, innovation, and development in Latin America began in the late 1940s, and have been characterized by great ingenuity and creativity. Yet, the richness of conceptual schemes and of empirical evidence contrast with the limited success in creating advanced science, technology, and innovation capabilities in the region.

4.1. Latin America's increasing science and technology development gap

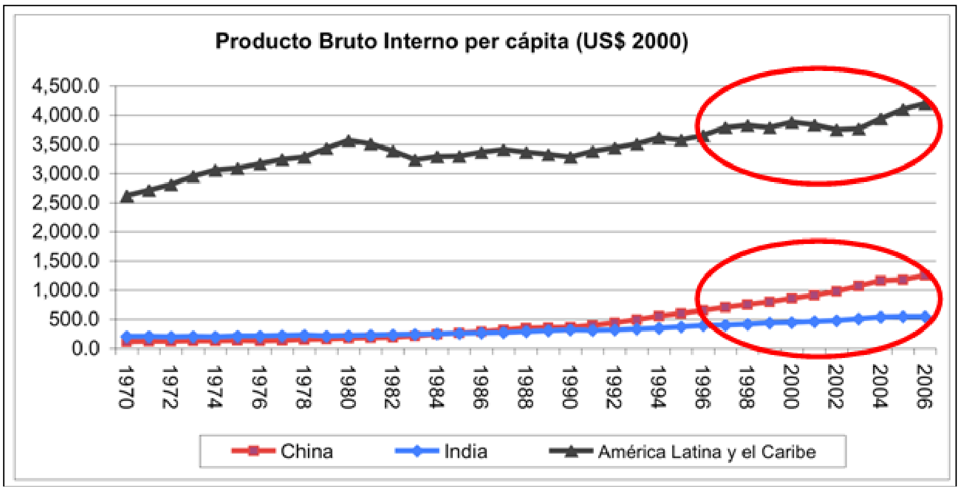
At present, Latin America lags behind not only of Europe, North America, and Japan, but also the emerging countries of Asia, which had similar levels of income per capita, and of science and technology capabilities in the 1960s and 1970s. For example, comparing the levels of income per capita with the investments in science and technology as a percentage of GDP during the last four decades, it is possible to appreciate a stark contrast regarding the situations of India and China on one side, and that of Latin America on the other.

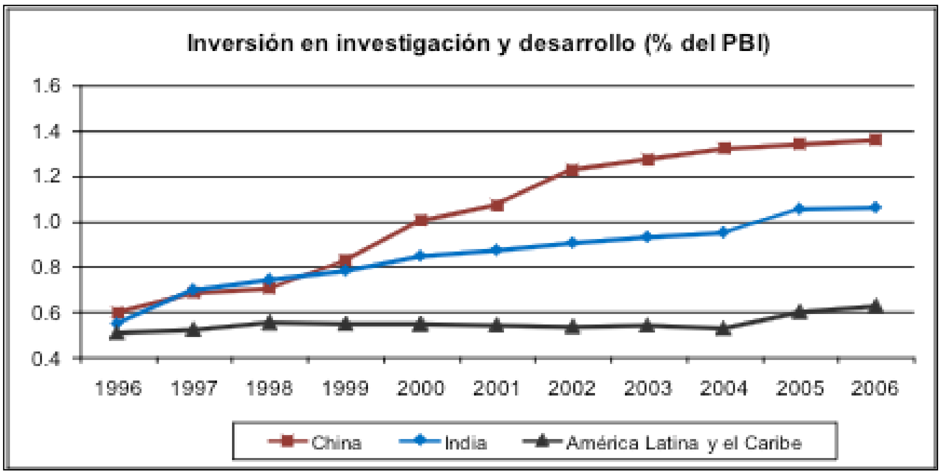
Latin America had a much higher GDP per capita than China and India during the last few decades, particularly between 1996 and 2006. However, during this period the two former countries have invested, on average, more than double in research and development as a percentage of their GDP (Figure 2), and the average economic rates of growth during this period were 9.74 percent for China and 5.65 percent for India, in comparison to the 2.85 percent for Latin America.

Between 1977 and 1986, the Republic of Korea had a GDP per capita similar to that of Latin America between 1998 and 2006; yet it invested a larger and growing percentage of its GDP in research, which in 1985 was more than double that of Latin America in 2006 (Figure 3). The average annual rate of economic growth for the Republic of Korea has been consistently greater than those of Latin

America during the last several decades: between 1977 and 2008, these rates were 6.53 percent for the former and 2.99 percent for the latter. Even though it is not possible to establish a simple causal relation between investments in science, technology, and innovation on the one hand, and economic growth on the other, since the 1960s, political leaders in Korea have been keenly aware that science and technology capabilities were essential for accelerating and sustaining development.

FIGURE 2: **Gap between the GDP *per capita and investments in research and development*: China, India and Latin America**
(In constant 2000 US dollars and percentage of GDP)

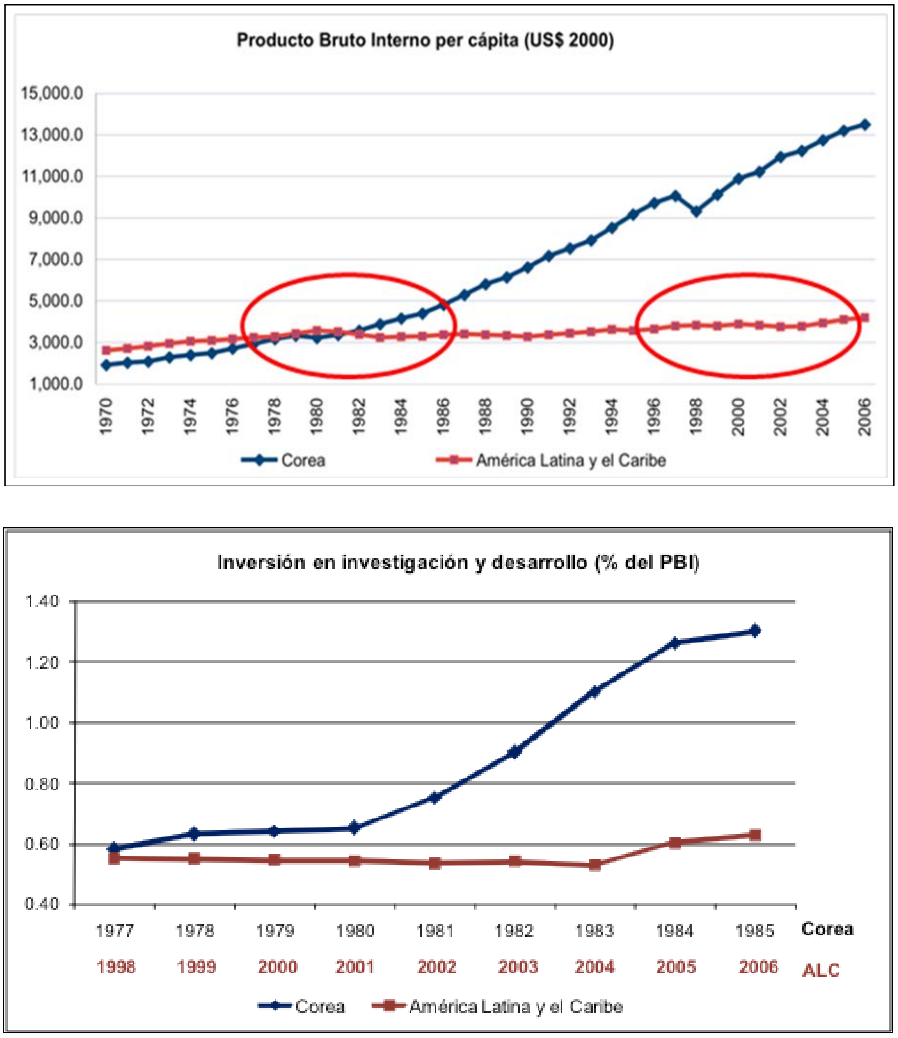




Source: World Bank, *World Development Indicators*, various years

There is no common reason for the divergence between ideas and practice in science, technology, and innovation policies in a region as diverse as Latin America. Some explanations point to a cultural heritage that did not value the practical use of scientific and technological knowledge; an excessive dependence on foreign investment for capital and technology; variations of the "natural resources curse" (van der Ploeg, 2011) that kept the region as an exporter of easy-to-extract raw materials with low knowledge content; and political upheavals that set back efforts to create and consolidate science, technology and innovation capacities. The indifference of political leaders and the ineffectiveness of public policies also loom as a likely explanation that will be explored further in this paper.

FIGURE 3: **Gap between GDP *per capita* and investments in research and development: The Republic of Korea and Latin America**
(In 2000 constant US$ dollars and percentage of GDP)



Source: World Bank, *World Development Indicators*, various years

4.2. Evolution of science, technology, and innovation policies in Latin America

The design and implementation of science and technology policies in Latin America evolved through several phases during the last six decades. The center-of-gravity of policy concerns shifted from one set of issues to another, which allows distinguishing five partially overlapping stages that can be clearly differentiated:

- An initial *science push* stage, which lasted from the early 1950s to the late 1960s.
- A *transfer of technology regulation* stage, which started at the end of the 1960s and extended through the 1970s.
- A *systems approach and policy instruments* stage that began in the early 1970s and lasted through the mid-1980s.
- An *economic adjustment and policy reform* stage that started with the Latin American debt crisis of the early 1980s, covered the lost decade of the 1980s, and waned in the mid-1990s
- A *systems of innovation and competitiveness* stage that began at the end of the 1990s and extended into the 21st century.

This last stage provided the basis for a period of renewal of science, technology, and innovation policies that started in the 2000s and continues to the present. Not all countries evolved through these stages at the same pace and in strict sequence, but in general it is possible to appreciate that the ideas and the practice of science and technology policy in the region followed the route summarized in Table 3, which describes the prevailing conception of the role of science and technology in development; the factors that condition science and technology capabilities; the interactions between science, technology, policy and strategies; and also identifies the role that international agencies played in the evolution of science, technology and innovation policies during the last 60 years.

The role of international organizations that provide policy advice and guidance has been quite prominent at the various stages in the evolution of science, technology, and innovation policies in Latin America. In the science push stage, the most active institutions were UNESCO, the Organization of American States (OAS) and the Inter-American Development Bank (IADB), which focused on supporting research and higher education. During the regulation of technology transfer stage the Andean Pact and UNCTAD played a leading role, helping to establish registries of licensing agreements, foreign investment and technology transfer.

The policy instruments and systems approach stage saw the Canadian International Development Research Centre (IDRC), the Organization of American States (OAS), the UN Economic Commission for Latin America and the Caribbean (ECLAC), the World Bank and, to a lesser extent, the International Labor Organization (ILO) and UNCTAD playing major roles in policy research and advice. This changed during the following stage, in which economic adjustment and market forces held sway, and the leading roles were played by the international financial institutions that favored the "Washington Consensus": the International Monetary Fund (IMF), the World Bank and, in a more limited way, the Inter-American Development Bank (IADB). In the innovation systems and

TABLE 3: **The evolution of science, technology and innovation policies in Latin America**

	Evolution of S&T policies in Latin America				
Lines of thought on science, technology and development	**Science push (1950-mid 1960s)**	**Regulation of technology transfer (1970s)**	**Science and Technology policy instruments (1970s-mid 1980s)**	**Economic adjustment and market forces (1980s-1990s)**	**Competitiveness and Innovation systems (2000s-2010s)**
Role of S&T in development efforts	Scientific advances are the basis for development	Technology is a commodity, negative impact of indiscriminate imports	Development should be reinterpreted as capacity to generat knowledge and technology	S&T are not important in themselves, market forces are sufficient	S&T innovation is the key to economic and social development
Factors that condition S&T capacities	Research capacity in universities and research institutions	Adequate regulation of technology imports, improved negotiation capacities	Supply and dempand of technology, policy instruments, alignment of explicit and implicit policies	Neutral economic policies, avoid market distortions (don't pick winners)	Balance between private initiatives and state intervention, production policies, promote entrepreneurship
S&T interactions, policies and strategies	Scientific research leads to technology and production (linear model)	Regulation of technology import creates demand for local S&T capacities	Interactions between elements of S&T system are key for policy design	S&T strategies and policies unnecesary, market forces are enough	Active, market-friendly policies and international insertion (liberalization)
Role of international agencies in S&T policies	Cooperation in higher education and scientific research (UNESCO, IADB, OAS)	Joint actions to regulate technology imports (UNCTAD, Andean Pact)	Comparative studies on S&T policy implementation (IDRC, IADB, ECLA, ILO)	Difussion of liberalization policies, "Washington Consensus" (World Bank, IMF, IADBs)	Dissemination of good practices in innovation and competitiveness (IADB, OECD, UNESCO, World Bank)

competitiveness stage, UNESCO returned to the scene, the OECD began to play a leading role, and the Inter-American Development Bank supported the science, technology, and innovation policy design and implementation efforts of most countries in the region.

As indicated before, these policies have not been as successful as envisaged in the mid-20th century. Table 4 describes the situation regarding investments in research and development in Latin America in comparison with other world regions. It is possible to appreciate that, despite a double-digit rate of growth during the first decade of the 21st century, the region still lags behind the European Union, the OCED countries, and the United States. The rate of growth of research and development investments as a percentage of GDP in China is quite impressive, especially so because the Chinese economy grew at a rate close to 10 percent per year during this period, and Latin America would need an extraordinary effort to even partially match the performance of the Asian giant.

TABLE 4: **Investments in research and development**
(As a % of GDP and growth rate 2000-2008)

Region	**2000**	**2002**	**2004**	**2006**	**2007**	**2008**	**Growth rate (% 2000 - 2008)**
Latin America	0.56	0.55	0.53	0.55	0.62	0.65	16,1
China	0.9	1.07	1.23	1.38	1.39	1.47	63,3
European Union	1.78	1.82	1.82	1.84	1.85	1.94	9,0
OECD countries	2.36	2.32	2.26	2.30	2.30	2.44	3,4
United States of America	2.79	2.61	2.54	2.60	2.66	2.78	-0,4

Sources: World Bank Development Indicators, RICyT

The growth in science and technology capabilities in Latin America can be largely explained by the performance of Brazil, which in 2007 accounted for 59 percent of the region's investments in research and development. Mexico accounted for 21 percent, while Argentina and Chile for 8 and 4 percent, respectively. This suggests that the global knowledge fracture is reproduced within Latin America, with just two countries accounting for most of the investment and capabilities in the region.

Initiatives to increase the supply of high-level scientists and engineers, and to create scientific research capabilities in universities and research centers, have increased the production of knowledge to a certain extent, but did not manage to close the gap between the region and the more advanced countries. For example, the number of masters and doctoral degrees awarded in Latin America increased sevenfold between 1990 and 2007, but in the mid-2000s the number of degrees awarded in the social sciences and humanities was five times greater than the sum of doctorates awarded in natural and exact sciences, medical sciences, engineering and technology, and agricultural sciences (Lemarchand, 2010).

The percentage of Latin American scientific publications listed in the Science Citation Index increased from 1.6 percent in 1990 to 3.4 percent in 2005, but in the 2000s this represented less than 50 scientific publications per million inhabitants, in comparison with the more than 300 publications per million inhabitants in the more advanced countries. Once again, the performance of Brazil, Mexico, and Argentina, to which Chile must be added, accounts for the lion's share of these publications (Painter & Zuñiga, 2010).

While patent statistics have serious limitations, they provide a general idea about the level of technological capabilities. During the last two decades, the percentage of world patents awarded to Latin American residents has remained at about 1 percent (Lemarchand, 2010). During 2005–2008, the relative position of the region in worldwide patent registrations per 100,000 inhabitants (estimated according to a normalized scale from 1 to 10) was 5.5 —a setback in relation to 1995–1998, when this indicator was 6.5. Also, in 2005 the Republic of Korea registered 150 patents per 100,000 inhabitants, while Latin America registered less than one (Painter & Zuñiga, 2010).

Data on the evolution of productivity make it clear that Latin America is below its potential: total factor productivity in the region has been decreasing since the mid-1970s (Lemarchand, 2010). A report prepared for the Inter-American Development Bank reached the conclusion that: "the slow economic growth of the region is due to the slow growth of productivity; in contrast with theory and the evidence from other regions, Latin American productivity is not approaching the frontier; and productivity in Latin America is approximately half its potential." (Daude & Fernandez-Arias, 2010).

The capacity of Latin American firms to innovate is rather weak; they are far from the world's technological frontier, and they invest little in research and development as a percentage of sales: 0.2 percent, in comparison with 1.61 percent for Europe and 1.89 percent for OECD countries. Most innovations are incremental, seldom involve radical technological change, and emphasize minor adaptation in products and services, production systems, and organizational practices. There is little public support for innovation, with less than 6 percent of enterprises receiving financial assistance from government agencies, in contrast with the 10–50 percent in Europe, depending on the country and sector, (Painter & Zuñiga, 2010).

Therefore, despite several decades of policy initiatives, Latin America has not managed to create and consolidate science, technology, and innovation capabilities that could effectively contribute to development and to bridge the knowledge fracture, both with other regions and within Latin America, which would provide the foundations to adequately address the challenges posed by the fractured global order.

Nevertheless, both at the national and regional level, there are recent initiatives to address the shortcomings in science, technology, and innovation policies. For example, in the case of Peru, which is a regional laggard with regards to public investment in research and development (with about 0.12 percent of GDP allocated for this purpose), a Consultative Committee appointed by the President has recently made several policy and strategy proposals that could quadruple investments in this field in five years (Comisión Consultiva, 2012).

At the regional level, the Inter-American Development Bank has been very active in supporting countries in the region to build their own capacities, and has explored the possibility of creating a regional program to promote the exchange of experiences and increase collaboration. Additional efforts to provide policy advice are being made by UNESCO, UNCTAD, the UN Economic Commission for Latin America and the Caribbean (ECLAC), and the OECD, which are engaged in policy reviews, training programs, regional events and the preparation of reports on science, technology, and innovation issues.

5. Concluding remarks

Considering the main features of the fractured global order that set the scene for development efforts, and the Latin American experience of the last sixty years and the current situation with regard to science, technology, and innovation policies, what is the role that policy advisors and policy advice institutions, should play?

As suggested by Swanson and Bhadwal (2009), Blindenbacher (2010) and Carden (2009), there is a need for adaptive policies, for governmental learning processes, and for linking research to policy making. But few policy researchers and advisors have had experience with these recent developments in the field of policy design and implementation. Therefore, a first task is to educate and train a new generation of professionals that should be aware of the way in which science, technology and innovation policies have evolved in Latin America, and also of the advances in policy-making in general. The rapidly evolving international context, with the emergence of the fractured global order and the key role of the knowledge fracture, makes this an urgent priority.

The new generation of policy advisors will be required to: (i) integrate information data and ideas on the fractured global order, and to interpret disparate and rapidly changing events, to manage the risks and take advantage of the opportunities it offers; (ii) pull together a host of long- and short-term issues and actions whose time horizons are constantly shifting, particularly in areas such as the training of highly qualified researchers, which involve urgent short-term initiatives that take time to bear fruit, and whose results are seen only in the long-term; (iii) effectively link ideas and action, thinking and practice, rapidly switching between conceptual frameworks and public policy realities to introduce adjustments that help to align both in a productive manner; and (iv) communicate and persuade politicians, public sector officials, business and labor leaders, and the general public of the soundness, timeliness, and urgency of the policy recommendations and initiatives.

Among the skills that such professionals should acquire is the capacity to anticipate trends in the various dimensions of the fractured global order and their interactions; understand their logic and explain the way they function; derive their implications for specific countries or sectors; and to identify and assess options considering their desirability and viability. This should be complemented with an intimate knowledge of the public sector and of the political context in which they operate; of the managerial and administrative demands imposed by policies and their instruments; and with adequate communications and persuasion skills. Finally, policy advice professionals should also be capable of designing and implementing appropriate monitoring and evaluation systems in order to assess progress and introduce corrections.

While there have been some initiatives to develop short courses, training programs, and conferences, we still do not have a clear sense of how to train a new generation of Latin American science and technology policy makers, policy advisors, and public sector managers to adequately respond to the challenges posed by the knowledge divide and the fractured global order. This is a task in which national think tanks, university research institutions, and international organizations could fruitfully collaborate in the coming years.

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