GLOBELICS

Working Paper Series

No. 08-03

ISBN: 978-970-701-963-8

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The Global Network for Economics of Learning, Innovation, and Competence Building System

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A policy model to foster coevolutionary processes of science, technology and innovation: the Mexican case

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Abstract:

This paper argues that in the context of the knowledge economy the coevolution of S&T and Innovation is crucial for developing countries. Two features limit such coevolution in this type of countries: (i) the conditions for generating variation, selection and retention (VSR) processes in both arenas are still incipient, there is neither the required size nor the diversity of agents and organizations, and (ii) even though there are links between the agents and functioning structures, they hardly generate bidirectional causal mechanisms. A set of policies are required to stimulate a coevolutionary process of S&T and Innovation; they should focus on the capabilities and institutions that are required for the emergence of the initial conditions and the promotion of new processes.

Drawing on the Systems-Evolutionary Perspective, and based on a comprehensive assessment of the Mexican STI policy 2000-2006, this paper discusses the failures to build virtuous coevolutionary processes of S&T and Innovation and suggests a three stage STI policy design to strengthen the VSR processes and the bidirectional causal mechanisms that contribute to such coevolutive processes.

1 Introduction[1]

The purpose of this paper is to discuss the coevolution between the science and Technology (S&T) [2] and Innovation (Innov) arenas from a developing country's perspective. It argues that in the context of the knowledge economy the coevolution of these arenas is crucial for this type of countries to transit to a development process.

The discovery that some Japanese firms as well as firms from Korea and other newly industrializing countries could compete successfully with their United States counterparts contributed to focus the attention of scholars and policy makers on the conditions of a successful catching up process. From the 1980s there has been a sudden increase of books and papers focusing on the function of S&T and Innov, and on their interrelations, for the development processes. In spite of the number of works tackling this issue, there is no work in the literature addressing specifically the problems of the coevolution between S&T and Innov, and also there is no conclusive historical evidence of the existence of a process of coevolution between these arenas in the postwar catching up processes. Drawing on Hobday (1995) and Kim (1997), it seems that most of these processes were driven by an extremely acute accumulation of innovation capabilities, which were fundamentally driven by learning from experience instead of by science or R&D activities.

However, the conditions for catching up and development seem to have changed since those days. There is little dispute about the argument that scientific and technological knowledge is essential for the development process. Thulstrump (1994), for instance, asserts that "highly efficient technologies, even low cost technologies and those adapted for local use tend to contain a large amount of research based knowledge". Lundvall (1992 and 1996), in turn, clams that the fundamental resource of the modern economy is knowledge, and suggests that knowledge and learning are more important in the current phase of economic development than in previous historical periods. The author asserts that "there is no alternative way to become permanently better off-besides the one of putting learning and knowledge creation at the centre of the strategy". (Lundvall, 1996)

Drawing on these arguments, it can be claimed that in previous periods coevolution between S&T and Innov was not crucial for development, but at the moment is

[1] A previous version of this document was presented in the IV Globelics Annual Conference "Innovation, Systems for Competitiveness and Shared Prosperity in Developing Countries", India, 2006; later it was presented in the Atlanta Conference on Science, Technology, and Innovation Policy, Atlanta, USA, 2007, and a shorter version will appear as Dutrénit, G. et al, "Coevolution of science and technology and innovation: a three stage model of policies based on the Mexican case", in Susan E. Cozzens and Elena Berger Harari (Eds), *2007 Atlanta Conference on Science, Technology, and Innovation Policy,* Piscataway, NJ: IEEE, (forthcoming).

[2] This paper integrates science and technology in a single population, which is called S&T and differentiates it from the other population that is innov. The authors are aware that there are important differences between science and technology; in fact an advance in science is not automatically translated in to an advance in technology and vice-versa. In addition, the business sector, which is the actor of the Innov activities, also generates technological knowledge, so technology could be treated also jointly with Innov. However, in terms of policies, it was considered important to distinguish the arena of Innov, associated exclusively with the business sector, from the arenas of science.

dramatically needed to sustain knowledge based[3] innovations and train the human resources, both of which are required for the transit of many countries into the development process.

There is a body of work that discusses the problems of coevolution between different populations. In this direction, Nelson (1994) discusses coevolution between technology, industry and institutions; Murray (2002) between Industries and National Institutions; Murmam (2003) analyses Industries and Academic Disciplines; Metcalfe, James and Mina (2005) discuss coevolution between clinical knowledge and technological capabilities of the medical innovation system; and Sotarauta and Srinivas (2006) relate Public Policy with technological Innovation as well as Public Policy with Economic Development in technologically innovative regions.

In the same line and based on the evidence that emerge from the Israeli case, Avnimelech and Teubal (2005 and 2008) analyse the coevolution of STI and Policies in high tech industries, and propose a type of life cycle model to foster innovation and the domestic venture capital industry. This model consists of three phases, from promoting business sector R&D, to the creation of a critical mass of start-up companies, and to the targeting of venture capital industry. Over time, direct and indirect support to the business sector R&D is required, but the combination of both and the appropriate measures evolve to satisfy new demands.

The Avnimelech and Teubal's (2005 and 2008) model is more directly applicable to countries, which have a quite strong S&T infrastructure. However, looking at most of the developing countries, with narrow S&T infrastructure, weak institutional building, biases in the incentive structures that affect the agents conduct, and dramatic social needs, such models should include the coevolution of: (i) S&T, and (ii) Innovation. They should consider more explicitly the strengthening of the S&T bases, changes in the regulatory framework and in the existent incentive structure, a broader focus on horizontal support and targeted industries, combining high tech with other technologies associated with revealed advantages and social needs.

Moreover, in developing countries there are two features that shape a coevolutionary model of S&T and Innov: (i) the conditions for generating variation, selection and retention (VSR) processes in both arenas are still incipient, there is neither the required size nor the diversity of agents and organizations, and (ii) the initial conditions show that even though there are links between the agents and functioning structures in both group of activities, they do not generate coevolutionary processes. Thus a coevolutionary process of S&T and Innov should focus on: (i) the capabilities, which are required for the emergence of the initial conditions for coevolutionary processes of S&T and Innov, and (ii) the institutions, which should change to move from the current linear model of STI to a coevolutionary one. This change from a linear to a non-linear structure requires a set of policies for both groups of activities.

[3] Freeman and Louçã (2001) analyses the interdependence and coevolution of science, technology, economy, policy and culture in England to explain the upsurge of the industrial revolution. However, not being the objective of his work to analyze the co evolution between science, technology and innovation, it offers several insights suggesting that such coevolution was crucial for the development of England and will keep being crucial for further development processes.

Drawing on the Systems-Evolutionary Perspective, and based on a comprehensive assessment of the Mexican Science, Technology and Innovation (STI) policy 2000-2006, this paper discusses the failures to build virtuous coevolutionary processes of S&T and Innov and suggests a three phases STI policy design to strengthen the VSR processes and the bidirectional causal mechanisms that contribute to such coevolutive processes.

After this introduction, Section 2 describes the conceptual bases of a coevolutionary model of S&T and Innov. Section 3 discusses key aspects of a dynamic coevolutionary model of S&T and Innov. Section 4 summarizes an assessment of the Mexican Innovation System and of the STI policy implemented in the last 6 years and discusses the difficulties to build virtuous coevolutionary processes. Based on this assessment, section 5 proposes a STI policy to generate and foster a coevolutionary model. Section 6 presents some final reflections.

2 A coevolutionary approach to S&T and Innov

There is a growing literature that applies coevolutionary concepts to the study of socio-economic systems, although challenging issues for transferring evolutionary concepts and insights from the biological to the social arenas have been recognized (Nelson, 1995, van den Bergh and Gowdy, 2003). Evolutionary models became popular in the organization and management theory, the innovation theory and the science policy theory since the late 1970s (Hannan & Freeman, 1977 and 1984; Aldrich, 1979; Nelson & Winter, 1982; McKelvey, 1982; Langton, 1984; Metcalfe, 1995).[4] Initially the authors began to focus on selection processes rather than agent's intentions in explaining organizational outcomes. Later on, coevolutionary arguments began to receive more attention (Norgaard, 1984 and 1994; Eisenhardt and Galunic, 2000; McKelvey, 1999; Lewin and Volberda, 1999; Baum and McKelvey, 1999; Levinthal and Myatt, 1995; March, 1994). This section describes the conceptual bases of the coevolutionary models, and analyzes the key features of the Science and Technology (S&T) and Innovation (Innov) populations and a set of institutional aspects of Science, Technology and Innovation (STI).

2.1 The bases of coevolutionary models

The standard evolutionary approach draws on a concatenation of three general causal processes (variation, selection and retention) introduced by Campbell (1969)'s model of change. The struggle over scarce resources is seen as a fourth process in the case of the social and economic evolution (Sotarauta and Srinivas, 2006: Aldrich, 2001).[5]

Variation, as the introduction of new entities, may be intentional, and so an actively generated alternative and solution to a problem, or blind and driven by environmental

[4] Winder, McIntosh and Jeffrey (2005) discuss the differences between a mechanistic versus an evolutionary dynamics focus.

[5] Struggle occurs within organizations as their members pursue individual goals, and within economies as various organizations pursue their own goals, and between economies each pursuing their own goals. Sotarauta and Srinivas (2006) argue that the struggle over scarce resources may lead to new varieties.

selection pressures. The selection process happens in a specific environment, which includes market and a set of non-market factors (especially institutions); it can be originated in two ways, first, there are forces that lead to differential selection, and, second, it can be a selective elimination of certain types of variations.[6] The evolutionary approach stresses adaptation to the selection environment, and as most ecological studies, it tends to ignore strategies and intentions of individual actors or collectives. The retention process involves the mechanisms for preserving, duplicating, or otherwise reproducing selected variations, so that the selected activities are repeated on future occasions or the selected activities appear again in future. Following Zollo and Winter (2002), replication is also an important concept in the evolutionary models; it refers to the process in which new selected variations are replicated elsewhere, in another organization or in another location, i.e. in those populations that may utilize them.

Variation, selection and retention are causal processes that explain how outcomes are produced from a given set of conditions including resources, incentives and other framework conditions. Very specific features of the environment frequently influence the trajectory of a population. Because environments differ, the same causal process can produce very different outcomes. Thus, in this approach the environment drives the evolution of the populations.

Since Campbell (1969)'s contribution, it has been recognized that evolutionary explanations apply to all phenomena that can be conceptualized as a variation and selective retention system, such as science and technology policies, public science system, university system, and science and technology system.

Coevolution refers to the evolution of different populations that are causally linked. Originally coevolution was confined to two populations; according to that a coevolutionary explanation requires two conditions: first, two analytically separable populations, each of which experiences variation, selection and retention processes, and, second, the evolution of one population influences the evolutionary path of the other. Later on, authors had also analyzed the coevolution between several populations, various levels within population, and in terms of populations and/or their environments. In this coevolutionary approach, and by introducing a complex systems' view, the actions of human agents in the coevolving populations to some extent shape their own selection environment.

A coevolutionary process could be either beneficial or risky for the populations involved; this depends on the particular causal relationship that links the parties. Biological ecologists have thought extensively about the relationship between different populations and they have identified six possible kinds of pair-wise interactions or processes: competition, predation, neutralism, mutualism, commensalisms and amensalism. (Murmman, 2002)

Even though it is already recognized that coevolution involves reciprocal causation between the evolving partners, there is limited knowledge about the precise causal

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[6] As argued by Nelson and Winter (1982), the concept of the selection environment directs attention to the fact that the intentional adaptation or a decision not to adopt often involves firm and inhabitant preferences, government policies and/or a wide set of market factors that range from macroeconomic conditions to the leadership of individual companies.

mechanisms that bring about coevolution. The conditions for the coevolution of the S&T and Innov populations have not been analyzed in the literature.

2.2 The coevolutionary features of the S&T and Innov populations

According to Volberda and Lewin (2003), coevolutionary studies should specify actors in terms of replicators (e.g., routines, capabilities) and interactors (e.g., individuals, units, organizations); processes in terms of variation, selection, and retention; and outcomes that result in a change of the emergent composition of a population over time. Following Murmman's (2003) recommendations, to know whether the variation, selection and retention model possesses explanatory power in the selected populations - the S&T and Innov, this section focuses on the S&T and Innov arenas and discusses: how new variants are introduced into these arenas, how consistent selection pressures are generated that eliminate some variants, and how the selected variants are retained over time to serve as the raw material for a new set of variants.

S&T and Innov are two activities that transform capabilities into outputs, thus the populations can be defined in both terms –capabilities and outputs. Two levels of analysis of the populations can be identified: individual and organizational.[7] This paper focuses on the populations of capabilities of S&T and Innov at individual level (**Table 1**).

Table 1 The S&T and Innov populations at individual level

Activities	Capabilities[8]	Outputs
S&T	Researchers	Ideas that are expressed in papers, patents, reports etc.
Innov	Engineers & technicians (including doctors in science and engineering) involved in innovation activities.	Product, process, services and organizational innovations, Trademarks, Patents, etc.

The processes that introduce new variations into the population of researchers are constituted by the increase in the number of S&T human resources, the creation of positions for new researchers in existent and emergent fields, particularly those focused on social needs,[9] and the present incentives to stimulate the existent researchers to enter in emergent fields and the creation of research group in existent and emergent fields, and by social and cultural environment. The selection process comes about because a set

[7] At organizational level, the population of S&T is integrated by research centers and universities, and the population of Innov by innovative firms. As the systems mature, monitoring at organizational level is more important than at individual level. But, when the institutional structures are still immature, as in the developing countries case, it is more relevant to map the individuals.

[8] Some indicators to measure the S&T population could be: Size, Type of capacities (curiosity-driven research vs. problem-oriented research, categories of the researchers, disciplines), and Patterns of behaviors (production of papers instead of books, interaction academy-industry, etc.). Indicators for Innov population could be: Size, Type of capabilities, BERD, and Patterns of behaviors (innovativeness, interaction academy-industry, access to public grants for innovation, hiring of PhD).

[9] As asserted by Sotarauta and Srinivas (2006) for the Indian case, "While external mechanisms like the new multilateral trading rules, including changes in intellectual property regimes, had a selecting influence on specific technologies and S&T institutions, a more important potential selector is basic social needs. In India, the dialogues about innovation have been more reactive to the West, and there has been less of an exploration of local markets and local needs—for example, basic infrastructure, vaccines or disaster warning and relief systems (for pharmaceutical and biotech)."

of researchers submits and grants projects in competitive research funds, applies to be members of the National System of Researchers and is recognized by this organization as researchers,[10] and submits and publishes papers in peer review journals. Framework conditions and the existent social norms in relation to STI determine what is socially accepted and affect the relationships between the STI Council and the academic research, shaping the selection process. The existence of permanent post with competitive income, the availability of resources for research, the prestige of the universities or research centers where they work, and also framework conditions and the particular social norms affect the retention process. What evolves when a researchers population changes is the frequency with which more researchers adopt internationally recognized behavioral practices.

The processes that introduce new variations into the population of engineers & technicians involved in innovation activities are constituted by the increase in the number of trained engineers & technicians that are able to work in the productive sector in existent and emergent fields, the creation of positions for innovation activities, and the existent incentives to carry out R&D activities and hiring engineers & technicians by the productive sector. The selection process comes about through submitting and granting projects in competitive research funds oriented to the productive sector, and submitting and granting R&D tax return. Framework conditions and the existent social norms in relation to STI determine what is socially accepted and affect the relationships between the STI Council and the business sector, shaping the selection process. Salaries and stability, stimulus for developing innovation activities (e.g. administrative and researchers carriers, innovation culture of the firms), and the prestige of the organization constitute the retention mechanisms in the population of engineers & technicians change, which is also affected by framework conditions and the particular social norms. What evolves when an engineers & technicians population changes is the frequency with which more engineers & technicians adopt internationally recognized behavioral practices.

The environment for the variation processes in both populations is conformed by: the educational system, the domestic and international labor market, the scientific and technological paths, the competitive position of the national industry, and the national postgraduate scholarship policy. The environment for the selection and retention processes is associated with: the organization of the research, the budget for S&T, the policy mix, the financial sector, the market structure of the hiring firms, the labor market, the regulatory framework, the existence of innovative firms and the innovation culture. The processes of variation, selection and retention are also influenced by economies of scale and externalities, learning processes and the culture.

The coevolution of the S&T and Innov populations depends on the existence of bi-directional causal mechanisms that link the evolutionary trajectory of S&T and of Innov. These mechanisms causally affect some of the variation, selection and retention processes in each population. If the evolution of S&T and Innov is causally linked, thus we can argue that there should be coevolution of both populations.

Following Murmman (2002), four types of relationships qualify as an example of coevolution of S&T and Innov, and can be seen as bidirectional causal mechanisms,

[10] The SNI (for its Spanish name) constitutes an important economic incentive as there is a montly payment to its members that represents a high share of the researchers' total income.

because the causation runs both ways between the two populations: (i) Competition: each population inhibits the other (e.g. competition between private and public laboratories based on prices), (ii) Predator/host: one of the populations exploits the other population (e.g. engineers & technicians of the private sector get benefit from knowledge of researchers through research contract or informal contacts, or researchers get benefit from the knowledge acquired through interaction with engineers & technicians to write papers or develop new patents), (iii) Neutralism: neither population affects the other, thus it can be evolution of each population but not coevolution of both, and (iv) Cooperation: interaction is favorable to both (named mutualism in the literature). For instance, in the case of the cooperation, four significant causal mechanisms link the evolutionary trajectory of S&T and Innov: the mobility of human resources (PhD students, technicians and researchers), training of human resources, the exchange of knowledge by formal means (contracts, seminars, stays) and informal networks, and lobbying by each on behalf of the other. These causal mechanisms bring about coevolution as they affect the variation, selection and retention processes that transform S&T as well as those that transform Innov.[11]

2.3 Institutional aspects of the coevolution of S&T and Innov

An institutional approach would contribute to understand how conditions for the operation of coevolutionary processes are generated. We need to understand: (i) What institutions favor VSR processes?, (ii) What institutions favor positive bi-directional mechanisms and which hamper the negative ones?, and (iii) How to move from one structure to another that allows coevolution?

The behavior of the co-evolving populations is governed by a set of norms that they have internalized over time, and is also influenced by restrictions associated to these norms. It is worth to differentiate between those norms that shape *informal institutions* by routines, habits, codes and agents' modes of behavior, and the *formal institutions* that emanate from constitutions, laws or regulations and set up the game rules. Both norms and game rules condition the VSR processes.

What institutions favor the VSR processes? The variation process, in terms of the diversity of behaviors and rationalities, is institutionally conditioned. For instance, if the norm of '*publish or perish*' has been introduced in the population of researchers, and at the same time it was strengthened by incentives derived from specific rules, thus the emergence of other behaviors associated with taking risks to explore new ways of knowledge production is difficult. Along the same line, if the idea that only low cost minor innovations are required to reach high benefits was introduced in the engineers & technicians population, it is difficult to generate behaviors associated with evaluating the risks of the emergence of competitors with higher innovation capacities.

The selection and retention processes of certain type of agents within the populations are also highly determined for the institutions. They act as filters for the expansion of certain agents in relation to others. For instance, the scholarships in the case of the researchers' population and the R&D fiscal benefits in the engineers & technicians' population are some of the bases for the selection process, which usually are more

[11] See Murmman (2002) for the case of Industries and National Institutions, and Murmam (2003) for the case of Industries and Academic Disciplines.

demanding and have more capacity to distinguish between different competitors than the natural selection.

What institutions favor positives bi-directional mechanisms and which hamper the negatives ones? Those institutions located in the interface between universities and firms are the main generators of rules to favor bidirectional mechanisms between both populations. Some of the main characteristics of these intermediary institutions that explain this role are: (i) they are created through agreements between producers and users, for instance between academic research groups and engineers & technicians groups; (ii) they clearly define the role played by the different agents –producers and users- in their creation; these agents also fix the operation rules; and (iii) they establish specific rules in relation to the participation that the personnel from the producers and users can play.

How to move from one structure to another that allows coevolution? The transit from a situation without coevolutive processes towards another where those coevolutive processes are generalized requires an institutional change. In particular, it is called for the emergence and consolidation of those institutions that favor the VSR processes and the bidirectional mechanisms.

3 Coevolution of S&T and Innov: towards a dynamic model

This section discusses key aspects of a dynamic coevolutionary model of S&T and Innov. Two equilibrium points based on coevolutionary processes are discussed, first, a low level equilibrium trap (LLET), and second, a high level equilibrium point that can only be reached by a strong Government Investment in STI and institutional changes. Graph 1 illustrates these two equilibrium points.

3.1 A basic coevolutionary process of S&T and Innov

If S&T and Innov are two populations that evolve, and there are links between the evolution of both populations, a basic model of coevolution of S&T and Innov can be based on the following functions: (i) S&T= f(Innov), and (ii) Innov=g(S&T). In these functions, S&T depend on Innov, and Innov depends on the levels of S&T.[12] The link between the two variables in the two functions is a complex matter since it involves both a push [Innov=g(S&T)] and a pull [S&T= f(Innov)] component. This means that there are both elements of efficiency -e.g. in the production of S&T and possibly in generating those types of S&T, which favor Innov (S&T includes training of skilled manpower for innovation), and elements of reactivity or interactivity between the two realms that is to what extent Innov will respond to the new opportunities opened up by S&T. Both elements would comprise the push effect underlying the equation Innov=g(S&T).[13]

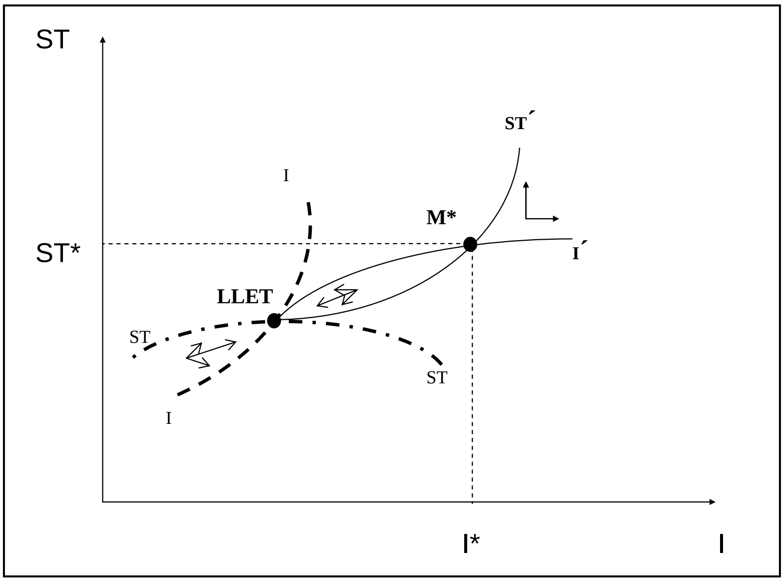
[12] It is important to distinguish between the activities of S&T and of Innov, on the one hand, and the levels, on the other, of a specific variable S&T that measures some scientific and technological activity or Innov that measures an innovation activity.
[13] Further research is needed to sort the ‘primitive’ relationships associated with both efficiency and reactivity in both push and pull.

An even more realistic model would make that Innov depend not only on the levels of S&T but also on the change or rate of change (d(S&T)/dt) to consider the possibility that the addition, or ‘delta’ of S&T, has a greater affinity to Innov than in the first model. This could result from more established areas (thus enhancing greater Innov reactivity); or when the most recent changes in S&T were accompanied by changes in governance of S&T in such a way that it may be easier than before for researchers involved in S&T to be more directly involved in Innov activities. This change also means that, for any level of S&T, Innov reactivity would be increased this time in what seems to be a more direct way (i.e. if those directly involved in S&T will do Innov).

The SW quadrant of Graph 1 illustrates this basic model; its equilibrium point is reached in LLET. The S&T and Innov curves, below the LLET equilibrium point, incorporates what would be “decreasing returns” (e.g to induce a certain ‘delta’ of Innov you need increasing ‘deltas’ of S&T, or the higher the level of S&T the more ‘delta’ of S&T is needed to induce a unit increase in Innov). Also to induce a unit increase in S&T you need increasing amounts of Innov (i.e. the higher the level of Innov, the higher the increase in Innov you need to induce a unitary increase in S&T). System failures are observed when the amount of S&T is below S&T* and/or Innov is below Innov*.

In terms of the coevolutive approach, the existence of decreasing returns is associated with both populations’ characteristics. Particularly, the relative reduced size of the populations, as illustrated by the position of the LLET point and even M* point in Graph 1, make it difficult to have a high degree of variation between the individuals. At the same time, the small scale makes the emergence of links between the populations less likely, which could conduct to increasing returns. In other terms, when there are high variation and virtuous bidirectional mechanisms between the populations, it is possible that more increasing return links come out. But when a reduced variation does not allow a high expansion of the researchers working in academic institutions, this originates an increase of the engineers & technicians working in firms less than proportional. At the same time, the limited size of the engineers & technicians population and the lack of links also determine that their expansion would also induce a less than proportional increase of the researchers. The scattered curves show scarce variation processes and limited bidirectional links, which are interpreted by functions of interaction between S&T and Innov capabilities with decreasing returns.

Graph 1 Phase diagram of a coevolutionary process



The slope of the g(S&T) curve is greater than the slope of the f(Innov) curve at the point of intersection. The equilibrium point is named low level equilibrium trap (LLET). In this point, to increase Innov by a unit you need a greater amount of S&T than that amount of S&T that will be induced by such a unit increase in Innov. This condition explains why the system is stable, in fact LLET is a stable equilibrium; there would be a coevolutionary process that conducts to this point, but the system will not move further from this point. That is why this is a low-level equilibrium trap. No coevolutionary process can move the system further from LLET, this is an attraction point. This shows the existence of some S&T capabilities and some Innov, but they cannot move significantly forward.

The positive difference between the marginal returns of Innov as a function of S&T, in relation to that observed by the S&T as a function of Innov, is explained by the immaturity of the NIS. This feature of the system could be determined by a higher capacity of the Innov population to transform the input of the S&T population than vice versa.

This disparity of the marginal returns is based on the differences observed in the selection and retention processes of both populations. The survival of a researcher is tightly related to the production of papers, which do not usually require many links with firms. These selection conditions suppose that the effect of S&T on Innov is less than proportional both in average and between marginal increases. Along the same line, the survival of an engineer or technician depends on his skills to generate product or process improvements that increase the benefit in the short-time. This usually does not require links with academic institutions. In the same way, this selection explains why the effect of Innov over S&T is less than proportional both in average and between marginal increases.

The marginal returns associated with Innov over S&T are lower than those generated by S&T over Innov. In coevolutive terms, this means that the selection and retention processes of the researchers' population tend to generate more links towards the engineers & technicians' population than vice versa. These features of the selection and retention processes are usually associated with the conditions of developing countries, and contribute to explain why in this type of economies the magnitudes of S&T and Innov are located in the scattered boxing ring. The coevolutive pattern described above would explain those NIS that can be represented by the scattered curves in Graph 1. This coevolutive pattern explains the dynamic around LLET that characterizes the developing countries, in other words, it explains a trap of low growth.

Despite a measure of S&T and Innov coevolution below the LLET, the overall NIS exhibits a sort of Dynamic Decreasing Returns. In other words, in the area within the two curves below the LLET equilibrium point, an increase in S&T will bring about an increase in Innov and this will increase S&T. But this process will lose vigor (smaller increases over time) and eventually come to a standstill. With a higher Innov curve, which means that the cost of Innov is higher in terms of S&T, or a lower S&T curve, as a result of the increase of the costs of S&T in terms of Innov, the LLET will be reached at lower levels of S&T and Innov.

In the basic model of coevolution of S&T and Innov described above, the only way to increase S&T and Innov would be with permanent government support, which would shift the curves upwards (curves depend on how much of the permanent support goes to S&T and how much to Innov). In other words, the system by itself will not grow, and any one-shot support will only lead to temporary increases in activity, which will end once such a support is withheld, the system thereafter returning to the LLET.

The only way to spark a new and more dynamic (or even permanent) coevolutionary process is by transforming the process into one characterized by *Dynamic Increasing Returns*. This could be visualized in terms of generating a new set of curves from the LLET point with the slope of the Innov curve being lower than the slope of the S&T curve. This means that the S&T curve would look like sloping upwards at an increasing rate while the Innov curve would look sloping upwards at a decreasing rate.

The new set of curves starts at the LLET point and would intersect at a new point, which can be named the critical mass point (M*). The system will not automatically shift from LLET to M*, since any deviation from LLET will make the system return to this point. What is needed is a discrete increase both in S&T and in Innov to shift the system to M*. Once this takes place, a new process of virtuous coevolution will start.

3.2 The required changes to transform the model

The above is a very simple model but it is highly suggestive. The shift from the LLET to M* requires three types of events: (i) a shift in both the S&T and Innov curves in the direction mentioned above, (ii) a big push in Government investment in both S&T and Innov in order to arrive at a point where a new virtuous coevolutionary process will start, and (iii) a set of policies to sustain the coevolutionary process. The former requires an increase in the efficiency and Governance of STI (policy may have a strong effect on it); the later an explicit Government attempt at triggering or sparking the new coevolutionary process. Thus, in order to reach the M* point, a set of policies are required to spark or trigger the process. But, after reaching the M* point, it is necessary to sustain the coevolutive process.

i) Increases in efficiency of S&T and Innov and in its Governance (maybe also broader institutional changes)

S&T and Innov should become more efficient and more reactive; this means a new S&T function which lies above the old S&T function (e.g. starting from the LLET) and a new Innov function which lies below the old Innov function. But this is not enough; it is also necessary that at M*, the slope of the S&T curve is higher than that of the Innov curve, which means that a unit increase in Innov requires less 'delta' S&T than the 'delta' S&T induced by this increase in Innov. This is the condition for virtuous coevolution to take off starting from M* in the NE direction (i.e. in the space between the two curves starting at M*).

How to achieve this? The selection and variation processes of both populations and the capacity to generate bidirectional mechanisms between them should change to generate the conditions in order for the *Dynamic Decreasing Returns* move towards the *Dynamic Increasing Returns*. This change will also depend on other norms that not only induce the ‘publish or perish’ behavior by researchers or the introduction of minor innovations to reach short-term benefits by engineers & technicians. Changes in governance of Universities seem to be crucial, such as greater power of young professors in ICT areas in setting priorities for allocation of funds to teaching and research; changes in the status of University professors from Government employees to employees of semipublic organizations; changes in the distribution of receipts from the patents and the licensing of technology between the University, the Department and the researcher; legal reforms to facilitate professors setting up start up companies and having these companies use indivisible equipment and services at universities, etc. A big challenge would be to identify a small number of profiles of University systems and University Governance in order to ascertain possible implications for shifting beyond the LLET point.

ii) A discrete increase in resources by the Government to shift the state from LLET to M*.

The jump from LLET to M* depends on the increase of the variation in both populations. The number of researchers and engineers & technicians should increase notably. A simultaneous effort and a strong one might be necessary, which should be distinguished from a routine, day by day effort of maintaining the system operation. What is required is a strong government investment in STI, over and beyond the current budget, which should be maintained at least for a short while. This may require a change in the governance of STI policy, with a more balanced division of powers between Ministries of treasury on the one hand and on inter-Ministerial committees dealing globally with STI on the other.

iii) Policies to sustain the coevolutionary process

To reach the M* point policies 'to spark or trigger the process' are required. Once the M* point is reached, a set of policies 'to sustain the coevolutive process’ are also required. Moreover, it is necessary to design policies to overcome the M* point. According to the initial conditions of S&T and Innov, it is essential to identify the adequate policy mix to generate a new set of curves that should intercept in the M* point. This issue requires further analysis.

The above arguments suggest that non-virtuous S&T and Innov coevolutionary process will happen if the Government puts more money without institutional/governance changes; or it introduces purely institutional changes without a significant investment in resources. Piecemeal policies will bring only temporary relief without setting the STI system into a new, largely endogenous, coevolutionary trajectory. Only both conditions make sure that a new S&T and Innov coevolutionary process is triggered and that the system failures that block the growth and endogeneization of STI is overcome.

4 The difficulties to build virtuous coevolutionary processes in the Mexican case

The analysis of the difficulties to build virtuous coevolutionary processes of S&T and Innov in the Mexican case is drawn on a comprehensive assessment of the Mexican key economic and social problems, the main characteristics of the NIS and the STI policy in this decade.

Mexico has five key economic and social problems: (i) low rates of growth in the last decades; (ii) an export specialization in medium and high tech industries linked to global chains, but with low R&D activities in Mexico; (iii) a trend towards competitiveness reduction; (iv) some international niches in industries based on natural resources, but which still do not compete on the bases of technology; and (v) high inequality and poverty. Overall, these key economic and social problems contribute to shape the NIS. Its performance is largely influenced by the evolution of the S&T and Innov populations. They have evolved slowly, as comparing to international trends, and at different pace and direction. Moreover, these populations confront serious difficulties to build bidirectional mechanisms.

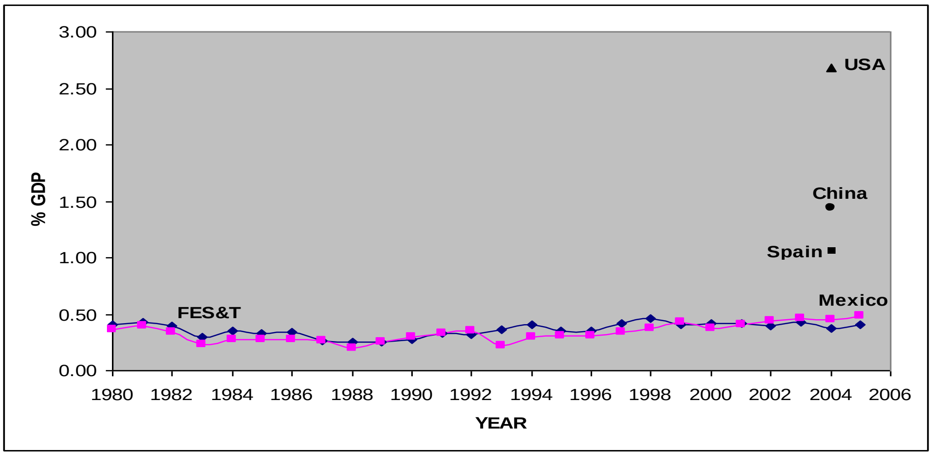
This section sketches the key features that shape the evolutionary path of S&T and Innov populations and the evidence related to the difficulties to build coevolutionary processes, the initial conditions of an extremely low level equilibrium trap and the context and the institutional setting for the selection process.

4.1 Weaknesses of the VSR processes and the bidirectional causal mechanisms

The VSR processes of both populations are influenced by very specific features of the environment, so they have to adapt themselves to it. Thus in some way the environment drives the evolution of the populations. A main factor of the selection environment that influences those processes is the limited political and social priority that government and society have traditionally assigned to STI. This is reflected in the low levels of investment –relative to international standards- in such activities by the different agents of the NSI. According to the goals set at the Special Programme for S&T 2001-2006 (PECYT for its name in Spanish), national expenditure in STI had to reach levels equivalent to 1.5% of Gross Domestic Product (GDP) by 2006[14]; Gross Domestic Expenditure on R&D (GERD), in turn, had to reach 1.0% of GDP. Figures show that from the 1980s, Federal Expenditure in S&T (FES&T) and GERD have levelled below 0.5% of the GD –see Graph 2, thus considerable gaps remain in meeting such goals. In addition, the Mexican effort is far below the international level. The stagnating trend in the public investment in STI has been accompanied by an unbalanced distribution of resources among STI activities in detriment of innovation, particularly in the case of the budget managed by the National Council of Science and Technology (CONACYT for its name in Spanish), as analysed below.

[14] National expenditure in STI includes the investments by the private, public and social sectors in R&D, postgraduate education and S&T services in a given year.

Graph 2 Evolution of GERD/GDP and Federal Expenditure in S&T/GDP, 1980-2005 (%)



Note: FES&T/GDP: Federal Expenditure in S&T as percentage of the Gross Domestic Product; GERD/GDP: Gross domestic expenditure on R&D as percentage of the Gross Domestic Product. Source: CONACYT

The variation process

1. S&T population

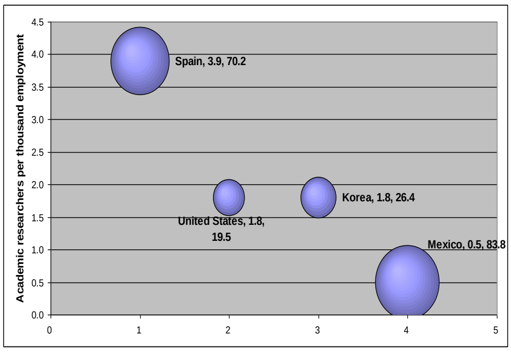
The processes that introduce new variations into the S&T population can be illustrated by the evolution of the number of academic researchers, the trend of the supply of S&T postgraduates, the geographical and institutional distribution, and a set of incentives to stimulate the existent researchers to enter emergent fields and the creation of research group based on new forms of knowledge production

Slow increase in the number of academic researchers. The academic community has grown over time at the pace of the population and employment. But as the initial conditions in the beginning of the 1990s were of a small community according to the size of the economy, the population and their needs, still it is. Being 23,000 individuals, they represent only 0.5% of thousand employments (see Graph 3). This amount and percentage is low as comparing to Korea, Spain and other well behaved economies. The academic researchers represent 83.8% of the total of researchers, which denotes an academics focus of the R&D activities in Mexico.

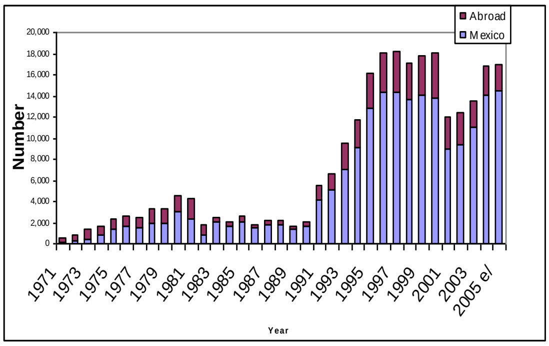
Strong stimulus to increase the supply of S&T postgraduates by means of scholarships. From 1971 on CONACYT has sponsored 136,000 scholarships for postgraduate studies in Mexico and abroad (Graph 3). There has been an increase in the number of scholarships assigned in Mexico as new postgraduate programs were established and increased their academic quality. Scholarships have been assigned in different disciplines and approaches, without much priorization. In 2005 this program represented a third of the CONACYT's budget, which suggest the importance assigned by the STI policy to the human resources formation. Unfortunately, this financial effort has not been matched with the creation of job positions for the retention of the postgraduates. Even though Mexico performs well in terms of the amount of supply of science and technology graduates as comparing to other countries, due to the size of the population, the results in terms of annually graduated PhD in Mexico and the coverage is less successful (OCDE, 2006).

Graph 3 Weight of the academic researchers **Graph 4 Evolution of the postgraduate**

in the total researchers and percentage of thousand employees, 2004



scholarships



Note: The size of the circle relates to the percentage of the academic researchers in the total of researchers.
Source: CONACYT

A high geographical and institutional concentration that affects the positive variation effect associated with the increase in the number of researchers and the supply of highly qualified human resources. There is a high institutional and regional concentration of the S&T capabilities, which attempt against the diversity and variation required for academic research. In addition, such regional concentration makes it difficult to focus on relevant problems at a local level. UNAM (Universidad Nacional Autónoma de México) concentrates 24.6% of the academic researchers. The main campus of the four largest institutions (UNAM, UAM –Universidad Autónoma Metropolitana, IPN –Instituto Politécnico Nacional - and CINVESTAV – Centro de Investigación y de Estudios Avanzados del IPN) are located in Mexico City, thus this state concentrates more than 40% of the Mexican academic researchers. In the last 10 years there has been an important concern with the regionalization of the S&T capabilities, as is stated in the S&T programs, but the results are still limited.

Some incentives to stimulate the existent researchers to enter emergent fields but limited resources. At the beginning of the 2000, CONACYT introduced, reformed or continued implementing several policy instruments and programs in support of STI activities. In 2001 17 Sectoral Funds were established, which are operated in conjunction with some Secretaries of State or other government organizations. They were designed as competitive funds and promote the development and consolidation of STI capabilities according to the strategic needs of each participating sector (e.g. basic research, economy/innovation, energy, agriculture, etc.). 30 Regional Funds were created with partnership from State or municipal governments, they intend to tailor STI capacities and development projects to the local demands. These are new instruments that can contribute to the variation process across sectors and regions. Unfortunately, only 16.4% of the budget of 2002-2005 was allocated to the sectoral and regional funds. Of these resources, applied research absorbed 9% and basic research 7.4%.

Incentives for the creation of research groups in existent and emergent fields. In the last administration some actions were undertaken to promote teamwork and networking for academic research. The calls for projects of many Sectoral and Regional Funds contain proposals for different forms of knowledge production, including individual and research groups. The committees that led the peer review process have some inclination for proposal submitted by research groups. As a result, in the case of the Sectoral Fund of basic science, funding for research groups has grown for 16.7% of the total budget in 2000 to 32.4% in 2005.

2. Innov population

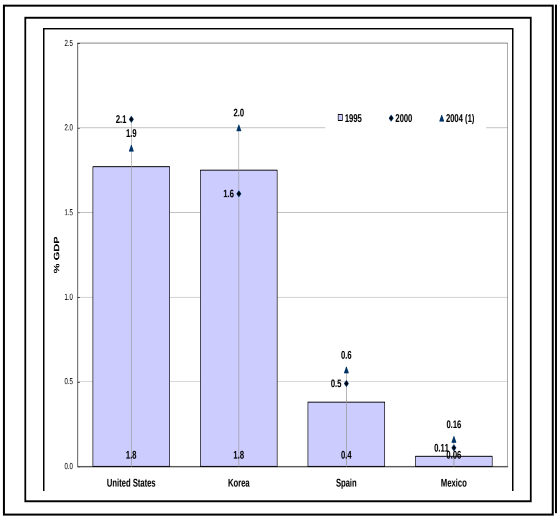
The processes that introduce new variations into the Innov population can be illustrated by the direct public support to R&D and other innovation activities, the trends of the expenditures in R&D and other innovation activities by firms, and the evolution of the number of trained engineers & technicians that are able to work in the productive sector in existent and emergent fields.

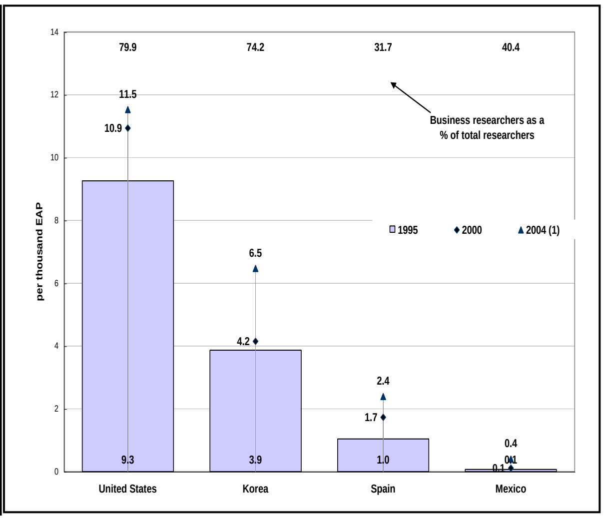
Limited and non-articulated direct support for innovation. Overtime, CONACYT has lacked the capacity to promote STI among the private sector, and recent changes in STI policy have contributed little to modify this situation. In 2002-2005, in a context of low investment in STI, the budget of CONACYT shows a relative balance in favor of academic researcher's compensation and human resources formation (57.3% of its budget), in contrast the resources for promoting innovation by the business sector are extremely low (3.8%), basically for the Sectoral fund of economy/innovation and AVANCE. This is a new and interesting instrument, which is oriented to promote innovation in private firms, preferably at advanced stages of development (the last mile); but they have received scarce resources. The most successful new instrument is the R&D fiscal benefits, as analyzed below, which is coordinated by the Finance Secretary. Large firms are those which mostly take advantage of it. Overall there is a bias in favor of large firms and limited resources are assigned to stimulate innovation by the SMEs.

Increase of the BERD over time but still low expenditures in R&D and other innovation activities by the business sector. There has been an increase of the business sector contribution to the GERD. The Business Enterprise Expenditure on R&D (BERD) has doubled from 1995 to 2005; but the actual 35.4% is still below the national target of 40% and far from the Lisbon target of 70%. Additionally, this change in the figures of the GERD sources of funding happens in a context of stagnation of the FES&T (see Graph 2 above). Thus the impact on the GERD as percentage of the GDP is limited; the BERD intensity as percentage of the GDP has grown from 0.06% in 1995 to 0.16% in 2004, which is extremely low as comparing to international standards (see Graph 5). The increase of the BERD is largely associated with the R&D tax benefit, which has grown from $36 million dollars in 2001 to $273 in 2005. The number of firms that claim R&D tax benefits has increased from 193, when this program was established, to 646 in 2005. Overall, during the whole period 2001-2005, 930 different firms have applied for, and many firms have applied in different years. The group of R&D performers is integrated by all size of firms; however 26 large firms explain 54% of the total. Even though this instrument has stimulated th involment of many firms in R&T activities, the extent to what the activities can be defined as R&D activities needs to be deeply analyzed. Particularly because the number of PhD working in the industry and in general R&D personnel (engineers & technicians) is still very low, and there are few R&D groups working in the business sector.

Graph 5 BERD intensity (as % of GDP)

Graph 6 Business firm researchers per thousand employments in industry





Note: (1) 2003 for Spain
Source: OECD: Main Science and Technology Indicators database, July 2006, and CONACYT.

Increase in the number of trained engineers & technicians that are able to work in the productive sector in existent and emergent fields. In the OCDE countries business firm researchers continue to account for the bulk of the researcher population. The Mexican case shows an important increase of the number of engineers & technicians working in research related activities in the business sector, both as percentage of thousand employments in industry (from 0.1% in 1995 to 0.4% in 2004, see Graph 5 above), and as a percentage of total national researchers (from 10.3% to 40.4% in the same years). In fact these figures reveal that the number of engineers & technicians have grown quicker than the academic researchers.[15] However, the figures are still very low in comparison to international trends.

The selection process

1. S&T population

The selection process in the S&T population can be illustrated through the procedures and number of researchers nominated by the National System of Researchers, the use of competitive funds to allocate research resources, and the evolution of publications in ISI journals.

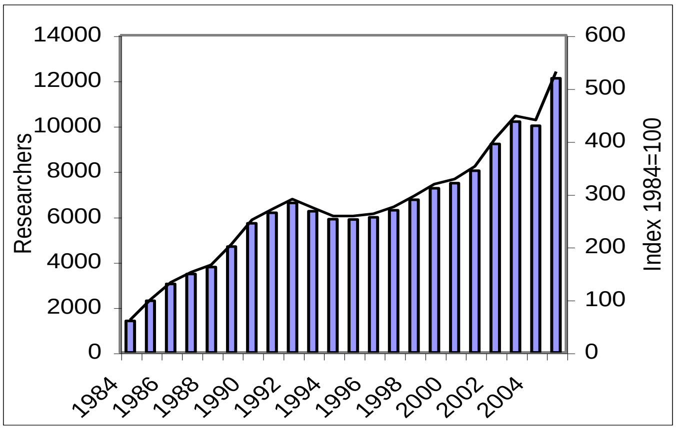
Researchers at the National System of Researchers. The number of researchers recognized by the National System of Researchers (SNI by its Spanish name) has grown fast (see Graph 7),[16] however there are only 12,096 of the 23,000 academic researchers recognized by the SNI, mostly government researchers in universities and public research centers. In addition, there is a trend to the ageing of the research community, as the hiring of young researchers is much slower that than the retirement of mature researchers'. The reduced size does not allow the required variety to sustain a robust

[15] The oficial data provides this trend, which is far away of the S&T community imaginary. Perhaps statistical problems are generating bias, such as a subvaluation of the business researchers in the part and a better recopilatiojn of information at the present. In any case this paper is based on official data.

[16] The SNI is one of the STI instruments with the longest tradition in the country, dating from 1984; its main goals include the promotion of the formation, development and consolidation of a critical mass of researchers at the highest level, mostly within the public system of higher education and research. The SNI grants both pecuniary (a monthly compensation) and non-pecuniary stimulus (status and recognition) to researchers based on the productivity and quality of their research.

selection process. In addition, the rejection rate at the present is only 25%; it has been reduced, which suggests a less tie selection process at least for the nomination of the lower levels.

Graph 7 Researchers at the SNI



Source: FCCT (2006)

Most of the research funds are allocated on the bases of competitive funds, which have a low percentage of success. The sectoral and competitive funds were introduced in 2001, as described above. They are the main mechanism to allocate research funds as only the UNAM has institutional funding for research. In the case of the Sectoral fund of basic research, the average percentage of rejection was 60% for the period of 2002-2005. In the case of the regional funds, it was 57%. These figures reveal a quite tie selection process.

Increase in the number of papers in ISI journals. As a result of the own trajectory of the academic researchers and the stimulus associated with the SNI, between 1990 and 2004 México has increased its scientific production at an annual rate of 11.24%; similar rates are observed in Brazil. However, this trajectory has not changed significantly its relative contribution to the world production, which is only 0.52%, below the 1.32% reported by Brazil. Mexico observes a relative specialization in physics; vegetal and animal biology; agriculture, stockbreeding and fishing; food science and technology; electric, electronics and automatic engineering; and electronics and communication technology. (Scimago Research Group, 2006) As analyzed above in the case of the number of academic researchers, there is a high concentration of the scientific production. 15 academic institutions, of 85, explain 70.4% of the Mexican ISI publications. Only one institution, the UNAM, generates a third of the papers.

There are more incentives for the curiosity-driven than for the problem-oriented research. The incentives associated with the SNI and the concern for increasing the number of publications in ISI journals influence the academic research towards curiosity-driven themes that are relevant for the discipline frontiers. This makes an attempt on research more oriented towards national problems, like health, environment or food.

2. Innov population

The selection process in the Innov population can be underlined by the use of competitive funds to allocate resources, and the importance assigned to the R&D fiscal benefits.

High rate of rejection in the public instruments oriented to support innovation in the business sector. The rejection rate of the Sectoral fund of economy for innovation in the business sector was 72% during 2002-2005, showing a high competition. This was the highest rejection rate of all the Sectoral and Regional Funds. AVANCE also observed a high rate of rejection of 63%. These rates are more associated with the limited amount of resources assigned to these instruments than to the quality of the proposal.

Increased importance of the R&D fiscal benefits. As referred to above, in 2001 R&D fiscal benefits were introduced in Mexico to help companies to invest more in R&D by reducing the company's tax bill. In contrast to other countries, this instrument has budgetary ceiling established annually by the Secretary of Finance, which has been growing rapidly since the creation of the instrument until today. The amount has increased from 4 millions dollars in 2001 to 30 in 2005. The rejection rate was very low, only 11% during the period of 2002-2005. The selection process has been quite loose, according to many specialists. In fact during this learning process, oportunistic behaviors were observed, in firms as in consultants, and this instrument has supported more development activities, and incremental design, than experimental research. (Santos and Dutrénit, 2007)

The retention process

The retention process is particularly limited in both populations. In the case of the S&T population, the effort to increase the number of postgraduate students has not been accompanied by the creation of new positions to hire them. In addition, bad retirement conditions and lack of retirement age show down the natural renovation process.

In the case of the Innov population, the lack of culture of innovation in the business sector, the limited numbers of firms that carried out innovation activities of world novelty and that differentiate administrative from technical careers do not favor the retention processes.

The last CONACYT’s administration was particularly interested on matching the knowledge supply and demand in strategic areas and promote lacking linkages between different agents, particularly university and business sector. In this line some actions were undertaken such as the creation of a jobs list, and a pilot program to support the hiring of PhD in the business sector. However, these new mechanisms are still far from being successful to changing the characteristics of the retention process

Bidirectional causal mechanisms

The Mexican case shows that there are limited links between the agents. There is a limited scope of the links between agents that produce and use knowledge, which does not allow the articulation to generate virtuous accumulative effects. Particularly, scarce cooperation for innovation is observed. The National Innovation Survey of 2001 shows that developments by innovative firms are largely based on internal sources and inhouse R&D (82%). They tend to cooperate more with other firms (14%) than with universities and research centers (4%).

The main instruments used by CONACYT for resource allocation do not stimulate linkages between agents. The main economic incentives to promote academia-business sector linkages in R&D activities are associated with the Sectoral fund of economy/innovation, AVANCE and a pilot experience of Public-Private Partnerships, which have received very limited resources. (Dutrénit, Santiago and Vera-Cruz, 2007) Additionally, the way selection is carried out, largely influenced by curiosity-driven targets, negatively affects the bidirectional causal mechanisms.

Section 2.2 describes four types of relationships, which qualify as an example of coevolutionary processes, and can be seen as bidirectional causal mechanisms, because the causation runs in both ways (competition, predator/host, neutralism and cooperation). In the S&T and Innov populations of the Mexican case they are observed in different degrees.

Some few experiences of competition are observed, like between the private and public laboratories based on prices. Limited experiences of predator/host are also observed, like cases where engineers & technicians of the private sector receive benefits from knowledge of researchers through research contracts or informal contacts, or researchers get benefits from the knowledge acquired through interaction with engineers & technicians to write papers or develop new patents,

Cooperation is more commonly observed, which means that interaction is favorable to both populations. The most commonly observed causal mechanisms that link the evolutionary trajectory of S&T and Innov are mobility of human resources and training. In contrast the exchange of knowledge by formal means (contracts, seminars, stays) and informal networks, and lobbying by each on the behalf of the other are less frequent. Unfortunately, neutralism is largely diffused in the Mexican case, which means that neither population affects the other, thus it can be evolution of each population but not coevolution of both.

So far the evidence illustrates that the evolutionary path of each population has been quite weak, due to the restrictions of each population's VSR processes. In addition, difficulties have been identified to build bidirectional mechanisms that support coevolutionary processes. Thus it can be argue that there have not been sustainable coevolutive processes between the populations of S&T and Innov. The selection environment, and particularly the budget constraints and the narrow STI culture of the society, has had a dramatic influence on its performance. Even though it is recognized that the actions of agents in the coevolving populations, to some extent, shape their own selection environment, the Mexican case shows weaknesses in the coevolutionary processes and so on the agents' capacity to radically transform their context.

It is worth to highlight that during the last administration a large number of instruments and programmes operated by CONACYT were introduced, but changes in the balance of incentives and actual impulse to the evolution of new social norms related to STI has been limited. The agents, mostly those in the public education and research system, face mixed stimulus for action in different directions. On one hand, some instruments have motivated researchers to increasingly carry out applied research oriented to innovation –

e.g. AVANCE, the Sectoral fund of economy/innovation-, and R&D with an orientation towards the solution of national problems –e.g. most of the Sectoral and all the Regional funds, but they have received very limited resources. On the other hand, strong incentives –both financial and in terms of recognition- have privileged curiosity-driven scientific research. In the same line, there are few economic incentives to promote academia-productive sector linkages in R&D activities. (Dutrénit, Santiago and Vera-Cruz, 2007) This has negatively influenced the evolutionary trajectory of both populations.

According to the discussion of section 3.1, and Graph 1, the evidence suggests that historically the initial conditions of the Mexican case are located in a extremely low LLET, with a relatively high level of the vertical axis (S&T) as referred to the horizontal axis (Innov). The different pace of the evolution of the populations, quicker in the case of the Innov population, seems to be moving that equilibrium point along the horizontal axis, but far away to the M*. But the weak financial effort of the last 25 years can only ensure to be attracted by the same LLET.

4.2 The context for the selection processes and the institutional setting

The Mexican context is characterized by a weak institutional building and multi-actor related governance, and by weaknesses of the STI policy design, which influences the incentives structure.

Weak institutional building and multi-actor related governance. The STI policy for the period 2001-2006 benefited from several changes in the regulatory framework and the accumulated learning from past experiences in policy-making and design. Among the legal reforms, those that stand up include the 1999 Law for the Promotion of Scientific Research and Technological Development[17], the Special Program on S&T 2001-2006 -the main document guiding STI policy in Mexico- (PECYT), and the Law for S&T[18] and the new CONACYT's Law[19] enacted as of 2002. The Law for S&T, in particular, set the bases for a "State Policy" in the field; STI policy gained greater priority under assumptions of an increased commitment from government organizations and adoption of an integrated Federal budget for STI.[20]

The Law for S&T placed CONACYT at the centre of the administrative coordination of the STI system, and under the direct control of the President of the Republic. New agents and structures emerged. However, the government's actions did not contribute to the recognition of this institutional capacity. As a result, CONACYT lacked the power to call and negotiate with other agents. The public efforts to coordinate the STI activities between the different ministries of the federal government and between the three levels of the government were insufficient to foster a greater structuration of the

[17] Ley para el Fomento de la Investigación Científica y el Desarrollo Tecnológico.
[18] Ley de Ciencia y Tecnología.
[19] Ley Orgánica de CONACYT.
[20] The consolidated budget includes not only the resources granted to CONACYT and its associated public research system, but all those funds allocated to STI by the diverse federal government organisations.

STI system. The governance of the system became quite complex. In addition, the types of governance and evaluation of the universities or research centers' activities lack of bodies that could be able to promptly set rules for implementing the STI policy's measures.

Weaknesses of the STI policy design. In 2001 the new government introduced a fresh STI policy based on a fresh policy mix. Principles shaping the new STI policy model include: (i) adoption of more strict quality principles and the look for pertinence of R&D carried out at the public research system, which was seen as a higher orientation towards the solution of national economic and social problems, (ii) explicit intentions to promote interactivity and coordination amongst agents in the NSI, (iii) commitment to regionalization of STI capabilities across the country, (iv) promotion of innovation activities, particularly in the private sector and, (v) opening up of spaces to the participation of ample groups in the Mexican society (PECYT, 2001-2006). These objectives translate into about 60 Funds and programs operated by CONACYT alone, or jointly with other organizations –see Section 4. The new policy program seeks to minimize "adverse selection" and "moral hazard" problems by means of a series of incentives and coordination mechanisms amongst agents in the NSI.

However, in practice, the STI policy mix and the funds allocation has kept a traditional shape. It is fragmented and based on an insufficient mass of resources to reach the defined goals. Particularly, the implementation of the innovation related instruments has been extremely slow.

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The improved design of STI policy confronts different problems though: (i) an institutional framework around the public research system whose changes have taken place at a very slow pace, (ii) very limited public investment in STI, (iii) inertias associated to policy tools coming from previous governments that kept their share in an stagnated budget for STI, and (iv) a slow process of policy learning within CONACYT.

These issues result in a series of incentives that send inappropriate messages for the renewal of the social norms and the change in the agents' behavior needed to sustain a renewed social contract for STI. As a result, there were no modifications in the economic incentives related to the instruments; therefore the signals to induce changes in the agents' behavior according to the targets of the new STI policy design were not strong enough. (Dutrénit, Santiago and Vera-Cruz, 2006)

5 A STI policy design to generate and foster a coevolutionary model[21]

Based on the generic coevolutionary model of S&T and Innov discussed in section 3 and on the assessment of the Mexican STI summarized in section 4, this section outlines a three phase STI policy design. This STI policy takes into account the initial conditions of weaknesses in the coevolutionary processes of the S&T and Innov populations that

[21] This section is based on a proposal of a new STI policy design for the Mexican case carried out by the authors and other researchers between November 2005 and July 2006. The team was integrated by Mario Capdevielle, Rosalba Casas, Daniel Malkin, Martín Puchet, Luis Sanz, Morris Teubal, Kurt Unger, Alexandre Vera-Cruz. FCCyT (2006) contains a more detailed analysis of the proposal.

have conducted to a low LLET. Thus it emphasises on the generation of coevolutionary processes (i.e. variation, selection and retention processes), reciprocal causal mechanisms and changes in the selection environment that allow to move the equilibrium point towards M* as a step to overcome this point. Such trajectory would make a great contribution to overcome the weaknesses and biases of the NIS, particularly its system failures, to generate and foster the S&T bases and the Innov activities, to satisfy social needs and to promote social and economic development.

We argue that in the Mexican case an STI policy design should consider the strengthening of the S&T bases more explicitly, changes in the regulatory framework and in the existent incentive structure, and a broader focus on horizontal support and targeted industries, combining high tech with others associated with revealed advantages and social needs. The main argument is that S&T and Innov co-evolve. The NIS, understood as a complex system, is taken as the unit of analysis to trace coevolutionary processes of S&T and Innov.

Five strategic goals are defined: (i) Strengthen the S&T human resources formation and insertion in the labor market; (ii) Consolidate and increase the S&T capabilities, by promoting quality and excellence of the research and increasing the international links; (iii) Increase the scientific and technological research of universities and research centers oriented to satisfy regional and national needs and promote knowledge transfer; (iv) Foster the R&D activities, the innovation activities and the innovation capacity of the business sector, and promote the technological diffusion within the business sector, particularly within SME; and (v) Favor collaboration and cooperation between agents at national and international levels.

5.1 Required conditions for the coevolution of S&T and Innov

As argued above, the VSR processes of both populations –researchers and engineers & technicians- and the bidirectional mechanisms that link these processes come about in formal and informal institutions, which emerge from the activities and the regulatory framework. As these evolutive and coevolutive processes take place in institutional frameworks, they transmit those conditionings to the performance of S&T and Innov, of the underlying structures of these variables and the stage of development. As the specific rules that were established for the agents and the social norms that they adopt in their behavior condition the mentioned processes, they determine the observed dynamics of variables, structures and stages. This institutional conditioning shows the key role played by the institutional change and the types of governance observed in the different institutions in the coevolution of S&T and Innov.

Some of the institutional changes observed in the Mexican case in the last 15 years have favored the coevolutionary processes described in section 4.1. As described above, these changes have emanated from both the legal reforms and important transformations of the behavior and practices of the agents. The selection processes in both populations have improved as a result of the introduction of competitive funds for research and R&D fiscal benefits. At the same time, the growth of the research centers and the SNI have contributed to the retention of researchers. The openness of new linkages channels between universities and research centers and the business sector have contribute to link evolutive processes of both populations.

The mentioned changes not only favor coevolutive processes, they also introduce new managerial capacities of the populations. In this way, the greater governance conducts to generate better mechanisms of adaptation of the organizations to the context and new forms of coordination. This, in turn, has repercussions on more appropriated selection and retention processes, deepening the coevolutive processes.

Following this trajectory, future changes should strengthen those aspects that favor coevolutive processes and reject those institutions that strike up these processes. Between the former changes, it is worth to mention the new incentives that foster university-business sector linkages, the transformation of the public research centers according to criteria of quality, excellence, pertinence and generational renovation, the promotion of a new culture in universities and research centers that privilege the links with the society, the fostering of a S&T culture in the society, and a new social contract for S&T.

5.2 The dynamics of S&T and Innov

To be able to put STI at the centre for satisfying social needs and promoting social and economic development is a gradual and cumulative process. The FES&T in 2005 only represented 0.4% of the GDP. This government's effort is far below the minimum magnitudes and percentages considered at international level to spark or trigger an autoreinforcing evolutive process of STI, the economy and the society, and thus be capable of jumping from LLET to M* point. It is expected that the additional magnitudes of public investment required in this process will generate an increase of the GERD funded by the government and executed by the government, universities and research centers and the business sector. After a gradual period of strategy maturation, the new incentives for innovation would trigger a substantial increase of the GERD funded by the business sector (BERD). The cases of Finland, Korea, Israel, Ireland and Spain illustrate, at different levels, this dynamic. However, the success of this process requires for the government to sustain this financial effort over a period of time, avoiding the risk of opportunistic behaviors by the agents –particularly the business sector- to take advantage of the additional public funds.

This is a three stage STI policy design; each stage involves different purposes of the evolutive processes of S&T and Innov, mechanisms for promoting variation, selection and retention, and changes in the environment. In each stage it is necessary to punctually introduce the required adjustments to move forward to the final goal. T1 and T2 stages correspond to the trajectory between LLET and M*, and the T3 stage would allow to overcome M*.

T1	**Strengthen S&T and Innov, modify the institutional context and consolidate a significant segment of innovative firms (2007-2012)**
T2	**Consolidation of the S&T and Innov capabilities oriented towards strategic sectors and acceleration of the innovation activities (2012-2018)**

T3	Virtuous dynamics: Excellence in S&T and generation of endogenous innovation activities in the business sector (2018-2024)

To make a scene for the future and discuss the STI policy design, we start with real data; the FES&T in 2006 was of $3,220 millions dollars. We suppose: (i) the FES&T and the GERD funded by the government will have a real annual increase of 20%, (ii) the growth rate of the GDP will be 5%, (iii) annual increase of the GERD funded by the business sector of 20% in the first years (higher than the 15% observed in the last period), but it tends to increase towards the end of T1. This trajectory would increase the GERD/GDP from 0.5% to 1.1% in 2012. The share of the business sector in the GERD would increase from 35.4% to 42.1% in 2012. This scene would position Mexico in 2012 in a situation like Spain in 2004.

This STI policy design suggests that the increase of the GERD funded by the public sector in the T1 phase will be oriented to strengthen the S&T capabilities, the R&D activities of the business sector and other innovation activities. Concerning the additional public resources to strengthen the S&T capabilities, direct and multiplied effects are expected. On one side, the generation of knowledge to solve basic needs and requirements of strategic sector will be made stronger; on the other, demands for new research both curiosity-driven and problem-oriented will be created. This process would nurture the variation and selection processes and create the conditions to look for new funding sources for S&T. Along this line, the stimulus to increase the human resources formation according to the specialized profiles required by the business sector to carry out R&D and other innovation activities would generate variation, increase the supply capacity of these human resources, and create conditions to involve the business sector in their funding. In addition, as researchers increase their participation in international networks, through selection processes, better access to international funding can be available.

Concerning the additional public resources to strengthen the business sector R&D and other innovation activities, leverage and catalytic effects are expected. As capabilities are developed in the business sector, new demands for subsidies and other government support will be generated, thus it will be necessary to keep increasing the GED funded by the government. However, as firms and other productive agents become involved in R&D and other innovation activities, a leverage effect of the public expenditures is expected and innovation began to be endogenized (T2 phase). In fact, because of the catalytic attribute of the innovation policy,[22] as new dynamics are generated in the business sector, and this sector increases the R&D and other innovation expenditure, the need of public intervention is reduced (particularly in T3 phase). Dynamic learning economies are also generated and contribute to this catalytic effect.

The additional mass of public resources should be both horizontal and oriented. Horizontal support will produce variation, the objective is to: (i) promote indiscriminately the identification and development of many projects and new knowledge areas, (ii) increase the S&T capabilities and generate a critical mass of innovative firms, and (iii) generate a variety of firms, sectors, technologies, areas of knowledge specialization and researchers. Oriented support will generate selection

[22] See Teubal, M. (1997 and 2002) and Avnimelech and Teubal (2005b).

processes, the objective is to: (i) promote the solution of problems oriented to satisfying the basic needs of the society and support the strengthening of economically strategic sectors, (ii) stimulate individual and collective learning trough STI activities, (iii) consolidate firms, sectors, technologies, areas of knowledge specialization and researchers, and (iv) consolidate emergent clusters.

The argument is that the STI policy should contribute to trigger an accelerated coevolutive process of S&T and Innov. This STI policy design put a great emphasis on fostering innovation to speed up the evolving trajectory of this population, but at the same time it ensures that the S&T population evolves harmonically, and bidirectional causal mechanisms between both populations are developed to ensure their coevolution. Even though different types of dynamic processes can be promoted, the dynamic process proposed here is one of those denominated "S&T and Innov push", which is based on the five strategic goals described above and is initially funded by an increase of the public resources mass.

The policy mix should change over the three phases according to the specific emphasis that each one stresses, to ensure the movement from LLET to M* and finally to overcome the M* point. Consistency between the allocation of resources between the different instruments should be kept. **Table 2** illustrates the evolution proposed for the Mexican case. Column one contains the policy mix in 2006; next column contain the proposed policy mix in each phase (including new instruments) oriented to generate variation, selection and retention processes in both arenas and promote bidirectional causal mechanisms. To start with this process, the government should invest important magnitudes to foster R&D and other innovation activities of the business sector. As it is expected, to trigger an endogeneization process of the innovation funded by the business sector, in the T3 phase it is predictable that the financial public effort oriented to this target will be reduced.

Table 2 Evolution of the policy mix, 2006-2024

	STI Instruments	%FES&T 2006	Expected composition FES&T *		
			2012	2018	2024
Capabilities S&T	National system of researchers	4.5	2.9	2.7	2.5
	Scholarships	6.5	6.3	5.9	5.5
	Posdoc positions	0.0	1.6	1.3	0.2
	Competitive fund for curiosity driven research	1.0	1.6	3.0	3.7
	Centers of excellence	0.0	2.1	4.0	6.2
	Support for scientific infrastructure	0.0	1.6	2.0	2.0
	Strategic sectoral funds	0.5	1.6	3.9	3.7
	Competitive regional funds	1.0	1.6	3.0	3.7
Capabilities Innov	Competitive fund for innovation	0.3	0.9	0.8	0.3
	Subsidy for R&D and innovation	0.2	3.9	3.7	0.2
	Support for technological infrastructure and technology transfer	0.0	1.6	2.0	0.5
	Funds for technology based firms	0.0	0.8	1.9	0.6
	Support for incubators	0.0	0.3	0.9	0.6
	Innovation program oriented to basic needs	0.0	0.3	1.1	1.3
	R&D fiscal benefits	9.8	9.5	8.9	5.6
Support for fostering STI culture		0.0	0.3	0.5	0.3
Other S&T expenditures (by Conacyt and different ministries)		76.2	63.2	54.5	63.1
Federal Expenditure in S&T		100.0	100.0	100.0	100.0

Note: *This expected evolution does not consider potential changes associated with the regionalization of S&T, and thus a distribution of expenditures between federal and regional governments.

Source: Own elaboration based on SHCP, Presupuesto de Ciencia y Tecnología, 2006; CONACYT, Situación Financiera de los Fondos, 2006.

Over time it will be also necessary to keep a sustainable financial effort to consolidate and increase the S&T capabilities located in universities and research centers. Social needs will probably change and new strategic sectors will emerge as the economy moves gradually towards economic and social development. As science is a public good, it will be necessary to sustain the financial public effort over time. Thus, as the country moves along the described trajectory, the policy mix will change, particularly the proportional allocation of resources between the different instruments, as illustrated in **Table 2**.

This type of trajectory, based on coevolutive processes, requires a gradual change of the agents' behavior, and the incorporation of new groups of the society in the STI activities. This also requires a change in the selection environment, particularly the institutional culture about the role of S&T in the academic sector, the innovation culture in the business sector, and the social perception of S&T and innovation.

6 Final reflections

This paper argues that in the knowledge economy context the coevolution of S&T and Innovation is crucial for developing countries. The evidence of the Mexican case shows that two features limit the coevolution of both arenas: (i) the conditions for generating VSR processes in both groups of activities are still incipient, there is neither the required size nor the diversity of agents and organizations, and (ii) even though there are links between agents and functioning structures, they hardly generate bidirectional causal mechanisms. Thus, failures were observed to build virtuous coevolutionary processes of S&T and Innov. Drawing on the Systems-Evolutionary Perspective this paper suggests a three phase STI policy design to strengthen the VSR processes and the bidirectional causal mechanisms that contribute to such coevolutive processes.

The proposed STI policy design has as a starting point the existence of initial conditions based on the endowment of capabilities, and the institutional framework. As many other developing countries, the Mexican case is one of weak initial conditions, thus the policy mix includes measures to overcome them. Such a policy would, through a chain of dynamic processes and events, lead first to favorable pre-emergence conditions and then to the successful targeting of new sectors. Throughout the three phases S&T, Innov and STI policy interact and co-evolve with the firms, organizations, institutions and sectors which they influence. This paper argues that one specific goal of the STI policy design is to achieve a 'critical mass' of resources, capabilities and activities that triggers a largely endogenous cumulative process within a reasonably short period of time. Such policy design looks at stimulating a dynamic non linear coevolutive model that avoids LLET traps and cycles, and moves both populations from the original LLET to another equilibrium point over M*. Success depends on: a) generating a critical mass of financial resources, capabilities (human resources, infrastructure, etc.) and activities; and b) change the policy mix.

However, the evidence suggests that in order to be able to design and implement such an STI policy it is necessary to acknowledge that a new policy mix is only a part of the story, it is also required to introduce institutional changes to induce new social norms that contribute to modify agents` behaviors towards generating coevolutive dynamics (changes of S&T that affect VSR and vice versa), and to reach agreements between different agents and to have a clear and consistent decisions taken by the federal administration. The Mexican case suggests that harmonization between agents and the buildings of a shared vision are key factors for the success of such an STI policy. As suggested by Sotarauta and Srinivas (2006) and others, there is a large difference in the images of future between scientific community, firms, families and individuals and those circulating in the policy field. The latter are pulled by innovation and technology lead visions, while the former have different visions, largely pushed from the past. The generation of a shared vision is required.

However, it is difficult to establish how the links between policies and coevolutive processes are generated. Further research is required to identify how the evolutive processes change the dynamics of the capabilities, the underlying structures and the evolutive stages, and how traps and cycles are avoided. Evidence suggests that investment efforts on capabilities without putting institutional reforms into practice and changes of the policy mix, and institutional reforms without a financial effort and changes of the policy mix are insufficient for generating the required dynamic and avoid traps of low growth and cycles that alternate phases of increase of S&T capabilities and decrease of Innov capabilities with others of declining of S&T capabilities with enlargement of Innov capabilities.

Some preliminary analyses, not reported here, suggest that other arenas also coevolved with S&T and Innov, such the policy-making learning and skills[23], and the institutions-organizations.[24] The evidence also suggests that there are several coevolutive processes on going. As asserted by Sotarauta and Srinivas (2006), "Technology or innovation policies or frameworks cannot be automatically equated with those for economic development. Innovative economies require mechanisms for reshaping science and engineering and reclaiming their outputs. Economic development policy processes can and should be differentiated more carefully by impact on economic development and impact on technological innovations…. A divergence is observed between the coevolution of policy with innovation/technology, the coevolution of policy with economic development, and the coevolution of technology with economic development needs."

A set of issues that require further research derivates from the analysis of the coevolutionary model of S&T and Innov and the STI policy design for the Mexican case: (i) theoretical issues related to the transit from a linear model to a coevolutive non linear model; (ii) type of institutional changes required for this transit; and (iii) type of harmonization between the agents to ensure the governance of the NIS.

References

Aldrich, H. (2001), Organizations Evolving, Sage Publications, London.

Antonelli, C. (2005), Models of knowledge and systems of governance, Journal of Institutional Economics, (1), pp. 51-73.

[23] Mytelka and Smith (2002) discuss the drivers and mechanisms of the process of policy learning. Such process cannot be separated from the development of the field of innovation research itself.

[24] See for instante Avnimelech and Teubal (2005a).

Avnimelech, G. and M. Teubal (2008), "From direct support of business sector R&D/innovation to targeting venture capital/private equity, A Catching-Up Innovation and Technology Policy Life Cycle Perspective", Economics of Innovation and New Technology, Vol 17(1).

Avnimelech, G. and M. Teubal (2005), "From Direct Government Support of Innovative SMEs to Targeting Venture Capital/Private Equity: An Innovation and Technology Policy (ITP) Cycle Model for Industrializing Economies", paper presented at the Beijing Globelics Conference

Avnimelech, G. and Teubal, M. (2004), "Strength of Market Forces and the Successful Emergence of Israel's Venture Capital Industry: Insights from a Policy-led Case of Structural Change", Revue Economique, Vol 55(8), pp. 1265-1300.

Campbell, D.T. (1969), "Variation and Selective Retention in Socio-Cultural Evolution", General Systems, Vol. 14, pp. 69-85.

Dahlman, K. and T. Andersson (2002), Korean and the Knowledge-based Economy: Making the Transition, OECD and World Bank Institute.

Dutrénit, G., F. Santiago and A. Vera-Cruz (2007), "Influencia de la política de ciencia, tecnología e innovación, sobre los incentivos y comportamiento de los agentes: lecciones del caso mexicano", Economía, Teoría y Práctica (forthcoming).

Dutrénit, G., A. O. Vera-Cruz, A. Arias, J. L. Sampedro y A. Urióstegui (2006), Acumulación de capacidades tecnológicas en subsidiarias de empresas globales en México. El caso de la Industria Maquiladora de Exportación, UAM/Miguel Angel Porrúa, Mexico.

Edquist, C. (1999), "Innovation Policy- A Systemic Approach", Linkoping University, Department of Technology and Social Change.

Edquist, C. (ed) (1997), Systems of Innovation: Technologies, Institutions and Organizations, Pinter Publishers/Cassel Academic

FCCyT (2006), Diagnóstico de la política científica, tecnológica y de fomento a la innovación en México (2000-2006), Foro Consultivo Científico y Tecnológico: México.

Freeman, C. and F. Louçã (2001), As Time Goes By. From the Industrial Revolution to the Information Revolution, Oxford, Oxford University Press.

Kim, L. (1997), From Imitation to Innovation: The Dynamics of Korea's Technological Learning, Boston, Harvard Business School Press.

Lundvall, B.A. (1996) "Information technology in the learning economy – Challenges for development strategies", background paper for UNCSTD Working Group on IT and Development.

Mckelvey, B., J.A.C. Baum and T. Donald (1999), "Campbell's evolving influence on organization science", in J.A. Baum, C.B. McKelvey (Eds.), Variations in Organization Science: In Honor of Donald T. Cambpell, Sage Publications, New Delhi, 1999, pp. 1–15.

Metcalfe, J.S., A. James and A. Mina (2005), "Emergent innovation systems and the delivery of clinical services: The case of intra-ocular lenses", Research Policy; Vol. 34, pp. 1283–1304.

Metcalfe, S. (1995), "The economics foundations of technology policy: equilibrium and evolutionary perspective", in Stoneman, P. (ed), Handbook of economics of innovation and technological change, Blackwell: Oxford UK and Cambridge USA.

Murmann, J. P. (2002), "The Coevolution of Industries and National Institutions: Theory and Evidence", working paper, FSIV02.14, Social Science Research Center Berlin.

Murmann, J. P. (2003), "The Coevolution of Industries and Academic Disciplines", working paper, WP03-1, Kellogg School of Management, Northwestern University.

Murray, F. (2002), "Innovation as coevolution of scientific and technological networks: exploring tissue engineering", Research Policy, Vol. 31, pp. 1389–1403.

Mytelka, L.K. and K. Smith (2002), "Policy learning and innovation theory: an interactive and co-evolving process", Research Policy, Vol. 31, pp. 1467–1479.

Nelson, R. (1994), "The Coevolution of Technology, Industrial Structure and Supporting Institutions", Industrial and Corporate Change,

Nelson, R. (1995), "Coevolution of industry structure, technology and supporting institutions, and the making of comparative Advantage", International Journal of the Economics of Business, Vol. 2 (2), pp. 171–184.

Nelson, R. (1995), "Recent evolutionary theorizing about economic change", Journal of Economic Literature, Vol. 33, pp. 48–90.

Nelson, R.R. and S.G. Winter (1982), An Evolutionary Theory of Economic Change, The Belknap Press of Harvard University Press, Cambridge.

Norgaard, R. (1984), "Coevolutionary development potential", Land Economics, Vol. 60, pp. 160–173.

Norgaard, R. (1994), Development Betrayed: The End of Progress and a Coevolutionary Revisioning of the Future, Routledge, London.

Parto, S., T. Ciarli and S. Arora (2005), "Economic growth, innovation systems, and institutional change: A Trilogy in Five Parts", working paper, MERIT-Infonomics Research Memorandum serie.

Santos, E.S. y G. Dutrénit (2007), "Adicionalidad de Comportamiento asociada a los Estímulos Fiscales en México", Innovación y Competitividad, año VII (27), pp. 4-10.

Scimago Research Group (2006), Atlas de la ciencia, http://www.atlasofscience.net/atlas/scriptat/rankingf_sp.asp?externo=1.

Smits, R. and S. Kuhlmann (2004), "The Rise of Systemic Instruments in Innovation Policy", International Journal of Foresight and Innovation Policy, Vol 1 (1 & 2), pp. 4-32 .

Sotarauta, M. and S. Srinivas (2006), "Coevolutionary policy processes: Understanding innovative economies and future resilience", Futures, Vol. 38, pp. 312–336.

Teubal, M. (1996), "R&D and Technology Policy at NICs as Learning Processes", World Development, Vol. 24 (3), pp. 449-460

Teubal, M. (1997), "A Catalytic and Evolutionary Approach to Horizontal Technological Policies", Research Policy, 25, pp. 1161-88.

Teubal, M. (2002), "What is the Systems of Innovation (SI) Perspective to Innovation and Technology Policy (ITP) and how can we apply it to developing and industrialized economies?", Journal of Evolutionary Economics, 12, pp. 233-257.

Teubal, M. (2006), informal notes.

Thulstrup, J.D. (1994), "Scientific Research for Development", Informal Working Paper, World Bank.

van den Bergh, J.C.J.M. and J. M. Gowdy, 2003. "The microfoundations of macroeconomics: an evolutionary perspective", Cambridge Journal of Economics, vol. 27(1), pp. 65-84.

Volberda, H.W. and A.Y. Lewin (2003), "Coevolutionary dynamics within and between firms: from evolution to coevolution", Journal of management studies, Vol. 8, pp. 2111–2136.

Winder, N., B.S. McIntosh and P. Jeffrey (2005), "The origin, diagnostic attributes and practical application of coevolutionary theory", Ecological Economics, Vol. 54, pp. 347– 361.

World Bank (2005), World Development Indicators, Washington, WB.