Interactions between Technology and Institutions: Tentative Framework to go beyond the Innovation System Approach

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> *The central focus of human activity has been, and continues to be, the effort by human beings to gain greater control over their lives by developing a structure to order their relationship to the environment. (..) Throughout most of history, the central uncertainty has been the physical environment; but as humans have increasingly gained greater control over the physical environment, with the development of science and technology, the uncertainties resulting from human interaction, the human environment, have taken overwhelming priority.*
>
> Douglass C. North (2003)

1. Introduction

The concept of system of innovation was born in the middle of the 1980s from a will to integrate institutional elements in the explanation of the process of innovation. This concept has known a growing popularity and has generated a great diversity of approaches. This diversity of interpretations and application fields makes innovation system approaches inevitable in order to build an analytical framework to explain interactions between the institutional structure within a society and technical change. Thus, on the basis of prior studies in the more particular case of the National Innovation System (NIS), we suggest an alternative and unique analytical framework in order to underline these interactions.

After pointing out the main theoretical contributions of this concept (II), this paper evokes two of the main limits which restrict the scope of this concept beyond the cases of developed countries. The evocation of these limits then enables us to underline the need for a clear distinction between technology and institutions (III) and the use of a theoretical tool able to integrate local specificities within a common framework (IV).

2. National Innovation System

In order to understand the concept of National Innovation System and to perceive the extent of this approach, it seems relevant to remind the consequences of each chosen word to indicate the National Innovation System. Thus, we will evoke the significance of the national framework, the different meanings of innovation and how the systemic approach could transform the analysis of technical change.

First of all, a part of the popularity of the concept of NSI is partly due to its *national* approach. If contributions about other types of Innovation System (sectoral or regional for example) can give an instructive view of the role of each actor in an innovating process, only the national framework seemed to be able to give part of the explanation of the relative heterogeneity of innovative behaviors in geographical space. One can more particularly wonder about the relevance of this national framework while an ineluctable globalization and an apparently increasing opening of the national economies towards the outside is taking place. Similarities of tastes, resources are part of the characteristics of a local community in general. Underlining the importance of a local framework is the first step (BELLON, NIOSI, SAVIOTTI and CROW, 1992) to justify this choice and the focus on the national level is the second one (LUNDVALL, JOHNSON, ANDERSEN and DALUM, 2002). These authors argue that the growing proximity brought by globalization increases the demand for understanding nation-specific systemic differences between innovation practices. Within a stable and regulated framework, one can think that instead of a standardization of the modes of organization, the international framework of exchange will admit and justify the coexistence and the persistence of these differences.

Then, we can underline the change in the understanding of *innovation* through the NIS concept. Despite some differences among authors in their conception of technology and its change, most of the presentations are based on an important idea. According to most of the authors who contributed to built the concept of NSI (FREEMAN, LUNDVALL or NELSON), and unlike the presentation of PORTER (1990), technology has to be understood as a part of codified information (that could be free and public or protected by a patent) and as a necessary part of experience, that belongs to individuals. The consequences of this approach are a relative complexity in explaining the diffusion processes and a partial reason of non-convergence of NIS among developed and developing countries. So the concept of NIS itself finds its origin in this

specific characteristic of technology: technological knowledge needs an interactive process between different categories of actors (users, producers or laboratories) to exist (AMABLE, 1991). Another agreement between most of these author deals with the Schumpeterian distinction between 'innovation' and 'invention', which implies that innovation is considered as an *economic fact* compared to inventions that could remain in the techno-scientific sphere forever (PEREZ, 2004).

Finally, and because of this conception on innovation, we can enhance the description of how the *systemic* approach could describe innovating behaviors more precisely. A social system, like any other system, can exist without equilibrium. It is possible to describe interactions between components without considering the existence of a long term combination of behaviors that would lead to a fixed point called "equilibrium". In the same way a living creature could be seen as an open system that never knows chemical or thermodynamic equilibrium (BERTALANFFY, 1973), a social system evolves and exists because of this impossibility. Another characteristic of this system that is linked to the former is the part of irreversibility related to technology. The National Innovation System can be considered as " stable " without the existence of equilibrium. It can integrate other forms of coordination rather than only commercial strategic interactions and underline the complementarity between the State and the market (and not only substitution) (BOYER, 2001). It can describe major innovation as an endogenous process (DOSI and METCALFE, 1991). It can finally admit that certain transformations of the dynamic laws of systems are irreversible for reasons that will be more precisely evoked in the continuation of this work by integrating phenomena such as learning processes or norms (BOYER, CHAVANCE et GODARD, 1991).

The concept of National System of Innovation, despite the multiplicity of approaches, offered an alternative framework to understand the process of innovation by underlining the importance of the national framework, by suggesting different views of what innovation is and by showing the complexity of behaviors through a dynamic and systemic presentation.

3. Technology and Institutions

A first limit of the concept on National Innovation System comes from the way institutional components are included in the system: As underlined by Charles Edquist,

"Organizations are formal structures that are consciously created and have an explicit purpose" when "Institutions are sets of common habits, routines, established practices, rules or laws that regulate the relations and interactions between individuals, groups and organizations" (EDQUIST, 2004). This confusion leads authors to introduce new actors, *institutional actors*[1], whose role is to give a precise orientation to innovation. This view consists in commenting the strength of links between these actors and to pinpoint the weaknesses of this system. But this will to include actors such as organizations, that is to say groups of individuals led by a common objective and organized by specific rules and habits, only suggests that different kinds of institutions, alternative to the basic institution that market is, are also important. Considering different ways of coordination between people does not allow discussing the nature of these relations and especially its change. However, the study of interaction between institutions and technology consists in discussing the changing nature of each of the components and not only the strength of relations between them: to evoke the relationship between two components of a same system, it is necessary to distinguish beforehand each of these components. Then, once the technological consensus and the nature of relationships are defined as distinct elements of a system, the relations between these elements will appear clearly.

Thus, in order to build an analytical framework, the first step is to define separately technology and institutions.

This distinction lead us to refer to Carlota PEREZ's work (1983, 2003 and FREEMAN and PEREZ, 1988) and to the concept of techno-economic paradigm. The concept of techno-economic paradigm is based on a typology of innovation: radical innovations and incremental innovation.

Incremental innovations are improvements of existing products. Interactions between users and producers lead to improve the power and the size of tools, to transpose existing technologies into[FSC2] new fields. The main characteristic of an incremental innovation is its relative predictability, and an expected product usually depends on time, like the increasing power

[1] R. NELSON and N. ROSENBERG, *Technical Innovation and National System*, in NELSON (1993), include Firms, Industrial Research Laboratories and other institutional actors like universities or government laboratories in the major institutional actors.

of computer processor or the size of LCD screens. Incremental innovation contributes to legitimate a most important innovation as a consensus.

Radical innovation can not be the consequence of the improvement of another innovation. An innovation can be considered as radical if it uses a new process or a factor that has never been used before. And being an innovation (and not only an invention), this new process can give a competitive advantage to the first producers who will utilize[FSC3] this new technology. Each radical innovation gives birth to a series of incremental innovations as long as a new discovery allows engineers to break the habits and to find a more promising starting point.

Between two radical innovations, during a certain time, incremental innovations create new products on an ever more controlled basis. The growing presence of the radical technical change and the succession of incremental innovations that reproduce methods from a field to another, leads to conceive technology as a temporary consensus. This consensus encourages producers and users to trust products and processes that refer to the *modern* technology: technology is entering[FSC4] a new age and its actual necessity is a secondary preoccupation.

The logic guiding these interrelated innovations, radical and incremental, constitutes a paradigm and characterizes its era. Each technological paradigm is built on the use of a specific factor, a *key factor* (PEREZ, 1983), which is characterized by four conditions:

- A low and decreasing marginal cost
- An apparent unlimited supply
- An all-pervasive potential
- A capacity to reduce the costs of capital, labour and products as well as to change them qualitatively.

(PEREZ, 1983)

These conditions can be illustrated by examples of successive key factors in history: coal (for steam power), steel, oil and finally the factor that generates the present technological paradigm, numeric information, that is to say codified and dematerialised sensitive signal.

This conception of the key factor combined with the dichotomy between radical and incremental innovation is what led Carlota Perez (1983, 2002, 2004) to suggest the powerful concept of a *techno-economic paradigm*. The present project is partly based on the difference between

techno-economic paradigm and technological paradigm. Technology itself has to be described as a tool, the changes of which are linked to institutions. But components like organisation modes (*"best practice" form of organisation* or *'ideal type' of productive organisation*) come under an evolutionary process of institutional change.

Thus, a technological consensus can be described by itself. Institutions (habits, cultural specificities, modes of organisation) intervene in the process of change but are not a part of the nature of technology. In this regard, it becomes possible to confer a universal character to this paradigm (GU, 2003).

4. A common framework to describe National specificities

The second limit of this concept is linked to the difficulty in comparing two (or more) NISs, especially if the level of development is not the same. This difficulty does not only exist in the national level analyses, but in most of the localised studies. This problem is generally the consequence of the will to integrate some specific institutional characteristics in the study to make a model as close as possible to reality. The fact that a nation has a specific way of creating and using technology because of its own culture and history is not debatable, and the work done on productive and innovative local systems by RedeSist[2] shows the relevance of such a study. But the way these frameworks are built makes transpositions absolutely impossible. The more we understand local productive and innovative behaviours, the more this work will be specific because of including in the whole model some cultural and historical points. But we need to consider another idea: the main differences between countries lie in the way technology is used, but not in the technology itself. So the comprehension of an economic phenomenon should not lead the author to consider each country as a particular case. The objective, instead of building a specific model for each country, should be to build a general framework with specific factors. These specific factors would be the nature of the relations between individuals, so these factors are institutions.

Thus, the alternative framework we propose to use has to get beyond this second limit. We argued that it has to treat separately the change of technological consensus, on one hand, and

[2] RedeSist is the research program coordinated by José Eduardo CASSIOLATO who developped the concept of « local productive arrangements ».

the evolving structure of relationships, on the other hand by offering a typology of the different forms that institutions can take. It also has to be a universal type of system that could be used with any country: the different categories of components of this system have to be able to include national specificity, in spite of the heterogeneity of political systems, level of development or natural resources.

The second step of such an analysis concerns the nature of relations between individuals. According to Douglas North, each effort made to reduce the uncertainty regarding the physical environment, that is to say the development of science and technology, implies a growing uncertainty resulting from human interactions. The growing command of tools created to save time and space leads people to believe in the same rules and to trust, at least for a certain time, the same structure of relations. It is these rules, these habits, written or not, that we can call "institutions".

By underlining the interactions between techno-economic paradigm and socio-institutional change, C. PEREZ (1983, 2004) describes common characteristics among institutional arrangements in spite of political systems. The "Age of Oil, Automobile and Mass Production" was characterized by a growing role of the state in the national economy, an expansion of higher education, a recognition of labor union and commercial innovations such as mass publicity or new credit methods. These are institutional changes linked to a technological paradigm that needs a standardization of the products and scale economies to survive. The question is now to know if the dynamic force that leads institutional structures to evolve is the same among countries and among technological revolutions and paradigms. In this perspective, what is needed is a typology of the forms taken by institutions. This classification can be done with the concept of "Institutional Forms" given by the Regulation School (BOYER, 1988, 1995) that distinguishes five forms.

Monetary and credit relationships describe the way monetary constraint is managed. This form includes the banking system and the tendencies of inflation or deflation on the national level. These relationships are transformed upstream along the path from a technological paradigm to another - by shifting resources from old industries to new ones - and contribute to the life cycle of this technology.

The wage-labor nexus describes the link between capital and labor. The evolutionary process tending to an efficient organization mode depends on the available technology and innovation depends on this relation. This form also includes the relations pertaining to wages and contracts. Work is a specific commodity, so its exchange has to be done in a specific institutional form.

The form of state intervention in the economy leads to define which goods or services cannot be exchanged through a "institution by default" - that is to say market in competition - because of their nature (health, school or even transport or energy). State is an economic actor whose action will influence innovation, directly or not.

The forms of competition define the competition intensity among markets and are necessarily linked to the role of the state. The competitive structure defines the shape of the life cycle of a technology and is closely related to radical and incremental innovations.

The mode of articulation with the international regime contributes to legitimate the national framework. In spite of the "multinational" aspect of the greatest firms in the world, the attitude of domestic industries facing foreign markets depends on a national will (WTO accession, local partnerships…). This form has an important influence in the technological diffusion process and is affected by domestic abilities.

Each of these five forms evolves and interacts with the technological consensus. This framework allows on the one hand to take into account the national specificities of each country and on the other hand to avoid separating "types" of countries with such criteria as "developed" or "developing". Every nation is organized according to these forms and every country faces the same technology during its history. The specific nature of arrangements excludes the comparison of relative strengths of these relationships. However, this framework is a tool to identify, for a particular country, which structural inertia slows the innovation process down and in which way the adoption of a new technology can (or cannot) allow institutional change.

5. Application

This tentative framework tries to get beyond two different limits in the application fields of Innovation System approach. The first one is the necessity to consider different « categories » of countries or regions. The concept of Institutional Forms is a universal and an all-

comprehensive tool to describe relationships between individuals. The second limit of the Innovation System approach is more implicit. The will of the first author who suggested this conception - Freeman defined a national system of innovation as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, and diffuse new technologies" - (FREEMAN, 1987) was to understand the reason for the dynamism of Japanese innovation. Then most of the approaches of NIS suggests to use innovation as the finality of the system ('all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations', EDQUIST, 1997). This approach led authors to build an analytical framework guided by the necessity to innovate in spite of institutional natural inertia. By proposing this framework, this project argues that technological change is necessary in a national development process but technology has to be a mean of transformation for institutional structure.

Thus, every country can be observed through this framework in order to identify what kind of uncertainty (in front of "physical environment" or "human environment") slows the process of development down. A study of the interactions between each of the structural forms and the technological consensus must lead to suggest which component is a necessary condition and which other component is a consequence of technological or institutional change. Then the experience of other countries can offer some solutions in order to accelerate the development process.

Conclusion

The role of the National Innovation System was very important because of all it brought to the economic theory and because of its diffusion among international organizations. But this legitimate will to partly explain technological change with institutions leads to forget the importance of institutional change in the development process. This analytical framework is built in order to understand how a social system evolves and not which institutional form slows down innovation and growth because of its natural inertia. Institutional forms are not obstacles but stages in the development process, so the interactions between all forms of innovation (technical and institutional) have to be understood as necessary links between structures of knowledge and rules built to face environmental uncertainty. Thus, if technology is the same among countries, if the need for institutional forms can be understood in a unique framework, we can assume that

the interactions are comparable and that the experience of any country can be useful to the others in order to understand and to encourage their development process.

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