HAS THE NATIONAL SYSTEMS OF INNOVATION (NSI) FRAMEWORK BEEN ACTUALLY APPLIED FOR POLICY–MAKING PURPOSES?

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ABSTRACT

This paper assesses whether the NSI approach has been applied for policy-making or just for policy analysis, and what the underlying economic rationales to justify policy action are. After reviewing the main topics associated with this framework, this work suggests that despite the widespread use of the concept, the NSI approach remains theoretically unfinished. It suggests that there are diverse interpretations regarding the underlying assumptions of this approach, its boundaries of application, the definitions of systems which are used, and, the definitions of innovation that are applied with theoretical and practical purpose. The paper takes us through an historical review of the literature and demonstrates that although definitions seem to be relatively similar, the meaning, scope and use of the concept spark much lively debate. For instance, it suggests that the concept of innovation varies from 'hard', scientific and technical conceptualisations, to 'soft', institutional or organisational conceptualisations. Similarly, the paper argues that the concept of a system varies from the 'aggregation of institutions or sectors' to the 'synergies originated from their joint operation'. It also argues that some internal limits of the NSI approach are still evident; for example, there is no clear delimitation of the characteristics of institutions and organisations the NSI should encompass or whether and to what extent there are national limits to the system.

Finally, the equilibrium and evolutionary rationales for policy intervention are discussed. In doing so, it is argued that: (1) independently of the underlying foundations of policy–making, the Arrow–Nelson rationale seems to be inevitable, due to the pervasiveness of the problem of knowledge reproduction and diffusion; and, (2) although the evolutionary–systemic approach provides a different and more detailed explanation of the economics of innovation, it has not been able yet to suggest significantly different policy measures from those which have been actually in practice during at least the last 25 or 30 years. In other words, the evolutionary–systemic approach provides a description of the economic system closer to the complexity of reality. While doing this, it offers an explanation to why markets could not be expected to be perfect; it provides a different rationale to understand a series of processes occurring in the real world, but in the last instance the conclusion is almost the same: left to themselves, those processes will make the system to collapse. Hence, some kind of intervention is justified to guarantee the adequate functioning of the system. It is argued that the change of rationale would imply a change in the way in which that intervention is perceived and implemented and this area constitutes the core for subsequent research efforts by the author.

INTRODUCTION

The 'national systems of innovation' (NSI) approach is a theoretical framework which was developed in the early 90's in the economics literature, specifically within the neo-schumpeterian and evolutionary currents of thought. It was intended as a framework for economic analysis, to better understand the environment within which science and technology policies were designed and implemented, emphasizing the context of application of these measures and the systemic nature of innovation processes. During the last ten years, different countries seem to have explicitly or implicitly adopted elements of the NSI framework in their policy–making processes to design and implement instruments to improve their innovative and economic performance[1]. However, it is not clear whether this adoption has implied structural changes in the way in which innovation policies are designed and in the characteristics of policies themselves, or it is simply used as a metaphor for describing national economies with an emphasis on its capabilities to innovate. Thus, the main objective of our research is to assess whether the NSI approach has been actually applied for policy–making or just for policy analysis, and what are the underlying economic rationales to justify policy action.

Despite the widespread use of the concept, the systems of innovation approach is still a theoretically unfinished framework[2] and presently, diverse interpretations co-exist at least regarding the following issues: its underlying assumptions, its boundaries of application, the definitions of systems which are used, and, the definitions of innovation that are applied with theoretical and practical purposes. Consequently, a secondary aim of this research is to attempt to develop further the theoretical basis and methodological dimensions of the concept. In the following sections we will briefly review the main topics associated with this framework and some initial reflections will be discussed to orient our future research.

FROM SCIENCE TO INNOVATION POLICIES

The development of science policies in industrialised countries seems to have followed clearly identifiable stages. First, in its ‘golden age’ from 1946 to 1967, the main problem appeared to be how to allocate the ever growing science budgets in a

1 See for example, OECD (1998) and Lundvall et al (2002).
2 Cf. Edquist (1997), and Lundvall et al (2002).

sensible way, namely elaborating a policy for science. Consequently, criteria for choice in science were discussed and structures for science policy making were developed[3]. As pointed out by Gibbons et al[4], such a policy became inadequate because it addressed itself to what was happening within scientific disciplines whereas the subsequent dynamics of knowledge production became more concerned with what was happening outside or along them.

With the institutionalisation of science policy and the routinisation of its practices[5], the attention shifted to issues of management of the national scientific capability and to a policy in which science was seen to support the objectives of other policies. This new perspective gave way to a stage of systematic debate of goals, strategies and assessment of the impacts of proposed policies. During this phase, basic research and the subsequent transfer of knowledge were considered the key issues for technology development. This trend, still based on a linear approach to technological processes, assumed that it was possible to induce innovation by promoting basic research and ensuring the availability of efficient transfer mechanisms. However, these policies had at least two interrelated flaws: firstly, they privileged a supply-side or science-push model, putting aside the fact that scientific knowledge is just one among the diverse sources of innovation. Secondly, the science-push model operates with regard to the dynamics of scientific knowledge paying no attention to the dynamics of industrial competitiveness, which is increasingly less dependant of fundamental discoveries and more concerned with combining different types of technologies with efficient manufacturing processes and high quality products[6].

3 Weinberg (1963); and, Salomon (1977).
4 Gibbons et al (1994).
5 Rip (1988)
6 See for example Branscomb (1992); and, Kodama (1992)

The deteriorating economic environment throughout the late 1970's and early 1980's forced another policy shift, one in which technology took the place of science as a more effective base from which to support national industry and economic performance [7]. Additionally, the understanding of the innovation process changed dramatically during the subsequent years. New interactive models, significantly different to the previous linear approaches, emphasized the central role played by diverse activities out of the sphere of research, such as the feedback effects between the stages of the innovation process which are related to the market and those related to technology and the diverse interactions between science, technology and other activities concerning innovation that occur at firm or at industry level[8].

Finally, during the 1990's and the initial years of the twenty first century, the concepts of knowledge based economy and learning economy have emerged to explicitly recognise the key role played by these two aspects in economic success[9]. This recognition is starting to evidence the need to move from policies that emphasise the importance of the systems and infrastructure that support innovation, to a new generation of policies which will be characterised by having innovation concepts embedded at the core of specific policy areas, such as those concerning the driving factors of the innovation process (competition, trade, etc), and the inputs (research, education, etc.) as well as outputs and effects (environment, employment, etc.) from the process[10].

7 Gibbons et al (1994).

8 OECD (1997).

9 See Lundvall, 1999.

10 See European Comission (2002)

TECHNOLOGICAL INNOVATION

Given the level of consensus that exists regarding the importance of scientific progress and technological innovation for the growth and competitiveness of firms and for the improvement of national economic performance, for the past three decades the economics and management literature has paid special attention to two essential aspects of this phenomenon. The first concerns the formulation and revision of synchronic and diachronic models[11] in an effort to identify and explain the constitutive elements as well as the dynamics of technological change. The second concerns the identification and analysis of the macro- and micro-level factors influencing and conditioning the innovative performance of firms. Among these, the systemic approach to innovation has emerged during the last decade as a particularly useful conceptual framework to understand the determinants and consequences of innovation in an effective way

Usually, the term innovation is used associated to its semantic character to denote novelty, which is misleading if we attempt to determine the degree of novelty or originality involved. Similarly, the use of this general notion does not permit to unequivocally delimit the fields and types of knowledge participating in the process as well as its driving forces. Thus, this work will be focused on the economic approach to innovation since it represents the most comprehensive and allows further conceptualisation and an ample view of its effects on other fields of activity.

From this perspective innovation is a techno-economic process by means of which firms increase their knowledge base to improve or replace their operation, processes, products or services. This new knowledge determines diverse types of

11 Static and dynamic models; the former emphasise the constitutive elements while the latter focus on the behaviour of those elements during time.

benefits for the firms, the users of products and technologies, and the whole set of agents that participate in the process of innovation, and are reflected in economic terms in the last instance. Due to its complexity and transdisciplinary character, the following categories are suggested to better understand innovation in its different perspectives: its *nature*, *taxonomy*, *outcomes*, and *sources*[12].

The first category –*nature*, allows the definition of innovation as a transdisciplinary process that involves among others scientific, technical, administrative, social behavioural and economic aspects. It involves at least three non-linear sub–processes: creation, production and diffusion, though the temporal relationship between these is vague and debated. There are many issues related to the nature of innovation, from the role of individuals such as entrepreneurs and champions, to technology transfer and the diverse types of collaboration between agents and organisations to complement their capacities as well as the alignment of the diverse elements involved in the process. A major contribution to the understanding of the nature of innovation is the evolutionary approach to technical change which has been developed since the early 1980's to explain at a detailed micro economic level the process of innovation[13]; this approach, will be explained further in the next section.

Related to the second category, several *taxonomies* have been proposed about the types and scopes of innovation, many of them related to the dynamics of industrial innovation[14] and the measurement of technical change[15]. They can be well synthesised in a three dimensional space with the following axes: (a) type of

12 See López–Martínez and Rocha–Lackiz (1998) and López–Martínez and Piccaluga (2000).
13 Nelson and Winter (1982).
14 Since the work by Abernathy and Utterback (1978).
15 See for example: Saviotti and Metcalfe (1984); Sahal (1985); and, Grupp (1994). The OECD manuals for scientific and technical activities and innovation include elements concerning taxonomic preoccupations as well; see OECD (1981) and, OECD (1997).

innovation (product or process); (b) scope (from radical to incremental); (c) architecture (from component to system).

From a techno–economic perspective, innovative processes may have two possible extreme *outcomes*, with an infinite variety in between: success and failure. In practice, it is difficult to categorise outcome in a once-and-for-all and static fashion. Often perceived failures may return as key steps to success in the learning process of particular innovations; and successes may prove more short-lived in their impact than initial results may have indicated. However, success and failure will always depend on both the partial results obtained in the different stages of the innovation process and the competitive market environment within which the firm launched the innovation.

Sources of innovation relate to the driving forces of innovative processes. This aspect has gained increasing importance especially for policy making. Initially, the fundamental debate focused on the science–push and market pull-models and choice of one or the other would influence both policy initiatives aimed at fostering innovation at a national level and firms' technology strategies at micro–level. Towards the end of the seventies, however, interactive models of innovation were proposed suggesting a two-way linkage between scientific and technological supply and market demand, with strong reciprocal influences[16] The recent literature on systems of innovation seems to have superseded this debate, though it could be stated that the empirical studies on innovation have not yet been able to integrate concrete problems to this framework.

16 For a complete discussion of these models see Rothwell (1992).

RATIONALES FOR PUBLIC INNOVATION POLICIES[17]

THE EQUILIBRIUM APPROACH

The basic economic justification for science and technology policies since the late 1940's, when the need to support the generation of basic knowledge was first identified, has been the 'market failure' argument. It has its origin in what some authors call the *Arrow–Nelson rationale* since these scholars stressed the economic importance of financing basic research[18] and suggested the economic justification to do so within the neoclassical framework[19]. According to this, it is not possible to attain Pareto–optimal allocation of resources to invention with the intermediation of equilibrium prices, since in the presence of market failures attributable to the characteristics of information as a commodity, the decentralised mechanisms represented by prices do not lead to optimum results. In this last case, government intervention is justified through the establishment of corrective measures designed by policy makers that have previously identified such failures.

It is widely accepted after Arrow, that there are three generic sources of market failures that affect knowledge generation activities. First, *indivisibilities*, which arise from the fact that R&D activity, can display economies of scale in any particular use, and in some cases, economies of scope across a wide range of uses. This usually creates strong incentives for firms to monopolise markets. Second, *uncertainty*, a condition inextricably associated to innovation and its diffusion. Closely related to the previous source, the existence of asymmetries of information explains firm's mismanagement of resources under profit maximisation behaviour. Problems of

17 Ample analysis of this subject can be found for example in Lipsey (1998), Metcalfe (1995a), Georghiou et al (2003), Hauknes & Nordgren (1999) and Bryant and Wells (1998).

18 See Nelson (1959).

19 See Arrow (1962).

adverse selection and moral hazard resulting from this unequal distribution of knowledge prevent the possibility of optimal market processes[20]. Uncertainty often leads firms to diminish their investment in innovative activities. Finally, *externalities* based on the characteristic of knowledge as a public good, meaning that it is non–rival and non–excludable. This problem can undermine firm's incentives to innovate.

Underlying this interpretation is the microeconomic theory of the firm which implies a particular view of technical information and knowledge, where this latter is generic, codified, immediately accessible and directly productive. From this perspective, technological knowledge and competencies are essentially just the possession of information which becomes a necessary condition to attain optimality, allowing rational optimising behaviour by firms; any restriction of these properties would violate the conditions for competitive behaviour. Despite its limitations, the market failure argument provides a strong general rationale including a guide to policy action and to determine optimal use of government expenditure[21].

Several measures have been used through public policy to correct market failures. These can be synthesised in the following mechanisms: to raise the expected returns by lowering R&D costs and restricting the exploitation of knowledge. The first mechanism includes directly or indirectly subsidising R&D expenditures, e.g. financing research programmes, the creation of information and innovation centres and tax incentives to R&D activities. The second solution involves the structuring of a patent system and the promotion of co–operative research ventures to internalise the externalities firms generate. Both mechanisms can be horizontally applied to the market where the failure occur or vertically applied to upstream supplier markets or

20 See for example Geroski (1995) and Metcalfe (1995a).
21 Cf. Hauknes & Nordgren (1999)

downstream user markets, affecting the supply and demand facing innovators[22]. The implications of this rationale can be summarised in the creation of favourable framework conditions to facilitate the smooth functioning of markets and to correct essential market failures by public provision or subsidising private production of science and technology activities. This has proved a strong argument for public R&D policies since the 1960's and had a synergic relationship with the trends and views concerning innovation at the beginning of that period, such as the linear model, the science–technology push view and the believe that technological innovation was dominantly embodied in capital goods.

THE EVOLUTIONARY APPROACH: DYNAMICS OF TECHNICAL CHANGE

The most recent conceptions and proposals on technological innovation and technical change —identified in various streams of evolutionary economics and coherently articulated for the first time by Nelson and Winter[23], attempt to simultaneously incorporate technology, the organisation in which innovations are generated or adopted, as well as the economic environment in which the organisation operates. Some of the main theoretical ideas behind these proposals include the following: first, markets constitute the selection environment within which organisations compete[24]. Second, technology is organised around trajectories and paradigms that determine meta–rules and operation strategies for industrial enterprises[25]. Third, technological learning is fundamental to the consolidation of the knowledge base of productive organisations and therefore the driving force of permanent innovative activity[26]. Finally, that this particular cognitive substratum permits specific behaviours that

22 Geroski (1995)
23 Andersen (1994).
24 Nelson and Winter (1982)
25 Dosi (1982; Metcalfe (1993)
26 Johnson (1992)

guarantee the variety necessary for the system to evolve[27]. It should be borne in mind that this learning refers to any process, within a productive organisation, by means of which the resources for generating and handling technical change are increased or strengthened[28]. This occurs within technological paths or trajectories and permits the accumulation of competencies that firms transform into routines[29].

These characteristics involve the historical and cumulative aspects of industrial development, since the present technological capabilities and innovations are the result of the way in which knowledge was managed in the past. Additionally, emphasis is made of the fact that firms fundamentally drive productive knowledge generation and technology development, though there are several other institutions devoted to similar purposes, like research institutes and centres.

From an innovation policy perspective, one of the main conclusions of this approach is that there are no unique policy prescriptions, nor are they necessarily or exclusively related to market failures. On the contrary, some of the sources of market failure are explained as conditions for the process of technical change to occur. Uncertainty for example, is an inherent characteristic of R&D and other innovative activities, these processes both generate and are influenced by uncertainty. On the one hand, there is technical uncertainty about the cost, time and achievement of expected results of an innovation project. On the other, there is uncertainty about the commercial success of innovations. Both factors inevitably imply that there are winners and losers among the firms engaged in technological competition and that it is not possible to assess *ex ante* the risk involved in technology development.

27 Metcalfe and Gibbons (1989)
28 Arrow (1962); Rosenberg (1982); Bell and Pavitt (1992)
29 Dosi (1982); Andersen (1992)

It is considered then, that the asymmetry of information is an essential component of competitive processes, for if all the agents involved possessed and managed the same information, profit opportunities would not exist for any of them. Within the process of technology innovation, this condition implies the existence of diverse forms of knowledge transactions between agents[30].

It is possible to observe as well, that the presence of externalities in the production of technological knowledge does not necessarily constitute a lack of incentives so that the private agents become involved in their production. On the contrary, the positive externalities of the generation of innovations can be an important reason to make joint R&D projects. These allow the average costs of development to diminish and the information on a given technique to increase, making its adoption less risky, or permit the application of derived technologies from previously spread innovations.

Similarly, the public good nature of knowledge has been questioned by the evolutionary approaches of technical change. First, it seems that knowledge and particularly innovations are partially rival goods, since given their specificity they only can be used by a limited number of agents. In the same way, technological knowledge is mainly exclusive, partly due to the existing systems of intellectual property and because firms usually have internal policies to limit the circulation of in–house developed knowledge. Finally, technology is constituted largely by tacit knowledge of the particular organisation that uses it and develops innovations. These factors significantly reduce the appropriation problems associated with the generation

30 Asymmetries in general, lead the process of economic selection and constitute the backbone for science and technology policy design; for it is necessary to choose what firms and institutions to support to obtain the desired general innovative performance. Thus, it seems that innovation policies should be more concerned with maintaining variety than to just preserving a competitive environment (Metcalfe, 1995a).

of technological knowledge, meaning that they do not necessarily constitute an obstacle for firms to invest in R&D projects.

Another useful conclusion to the design of science and technology policies concerns the type of the measurements adopted. The traditional approach almost exclusively leads to horizontal policies and instruments —such as the necessity to maintain open markets for the competitive process to occur and to rely on a suitable system of intellectual property. The evolutionary theory, in contrast, emphasises the *possibility* to explore a great variety of mechanisms that can be horizontally and vertically implemented. Given the assumption that policy actions must be directed mainly to preserve technological variety, these mechanisms are intended to increase the learning capacities and the creativity of the firms, allowing them to compete successfully[31]. In this way, innovation policies are justified not in terms of the welfare analysis, but in providing the conditions to improve the competitiveness of the national industries.

NATIONAL INNOVATION SYSTEMS

Associated with the evolutionary theory of technical change the national innovation systems (NSI) approach has been attracting attention since the beginning of the 1990's. Although the systemic approach in science and technology policies could be traced back to the late 1960's[32], its modern conception was first used in published form by Christopher Freeman[33]. However, he attributes the concept to the Swedish economist

31 Metcalfe (1995a); Lipsey (1998). However, it is recognised that the diversity of behavioural rules that determine firms' innovation strategies and allocation of resources, as well as, the wide institutional structure which supports innovative activities at firms, greatly difficult the analysis and design of innovation policies.

32 It was developed at the OAS to promote the articulation of science and technology policies with other areas of government planning. In fact, explicit recommendations of the UN, the OAS and the Inter American Development Bank in this sense led to the gestation of government agencies responsible for elaborating and implementing science and technology policies in most Latin American nations. See Sagasti (1983)

33 Freeman (1987); see Edquist (1997).

B.A. Lundvall[34], who probably based on the work by Frederich List on 'national production systems' and von Hippel's ideas on informal technical collaboration among firms, transferred the emphasis to user producer interactions within the national economy[35]. The ample diffusion of the notion took place after the publication of two collaborative works of different nature and characteristics; one coordinated by Lundvall himself and the other by Richard Nelson[36]. The former was the result of a homogeneous effort to theoretically develop the concept, while the latter was an attempt to apply the idea to the elaboration of a set of methodologically heterogeneous national case studies.

In the book coordinated by Lundvall NSI are defined as a set of elements and relations that interact, within national boundaries, in the production, diffusion and use of economically useful new knowledge. The core of the Aalborg group argument lies in three basic assumptions: (i) that knowledge is the most fundamental resource in the economy and learning is the most fundamental process; (ii) that learning is an interactive and socially embedded process which takes place within an institutional and cultural context; and (iii) that the role of national states has been recently challenged by the processes of internationalisation and globalisation. Subsequently, they characterise innovation systems as open, heterogeneous, self–reproductive and dynamic social systems within national boundaries, where the processes of learning and innovation occur.

Nelson and Rosenberg[37], for their part, consider a NSI as a set of institutions whose interactions determine the innovative performance of firms. They define

34 See Niosi et al (1993), Freeman (1995), Edquist (1997) and Lundvall et al (2002). However, in this latter contribution Lundvall offers a different source of influence.

35 Lundvall (1988).

36 Lundvall (1992) and Nelson (1993).

37 Nelson and Rossenberg (1993).

innovation in a broad sense as the process by means of which firms master and put into practice product designs and new parallel manufacturing processes. While the Aalborg approach attempts to build a theoretical framework oriented to the sources of innovation, the Nelson–Rosenberg one explicitly avoids theoretical constructs and is mainly oriented towards setting a more or less common structure to carry out studies about the conditions surrounding innovation activities on a national basis.

Subsequently, other authors have conceptualised NSI in terms of policies that affect innovative performance. Among them, Wijnberg[38] defines the system as the sum of interactions between a specific public authority and the industries that include the firms whose behaviour is most influenced by the former. Similarly, Metcalfe[39] defines a NSI as a set of agents, which contribute to the development and diffusion of new technology, providing the framework within which governments form and implement policies to influence the innovation process.

While definitions are relatively similar, the debate is very lively and thorough regarding the meaning, scope and use of the concept[40]. First, the concept of innovation itself varies widely from 'hard' —scientific and technical conceptualisations, to 'soft' —institutional or organisational conceptualisations. Second, the concept of system varies from the 'aggregation of institutions or sectors' to the 'synergies originated from their joint operation'. Similarly, there are differences concerning whether the emphasis should be put on the elements, in their relationships, or on both. Third, some internal limits of the NSI approach are still evident; for example, there is no clear delimitation of the characteristics of institutions and

38 Wijnberg (1994)
39 Metcalfe (1995a).
40 See the introduction of Edquist (1997); and, Alcorta, L. and Peres, W. (1998).

organisations the NSI should encompass. Finally, there is the issue of whether and to what extent there are national limits to the system.

In another important contribution to the theoretical background of the concept, Edquist has identified the following common characteristics of the different main approaches[41]:

1. Innovation and various learning activities are at the centre of economic processes, in contrast to conventional mainstream economics.
2. The approach of NSI is holistic, and interdisciplinary, in as much as it allows for the inclusion of not only economic factors influencing innovation, but also institutional, organisational, social and political.
3. The NSI approach recognises the importance of using a historical perspective.
4. The notion of optimality is absent from the NSI approach. In sharp contrast to neoclassical economic theory which assumes it to be valid for all market economies, and treats all as the same.
5. Interdependence and interaction between the elements in the system are one of the most important characteristics. These relations are extremely complex and often characterized by reciprocity, interactivity and feedback mechanisms. Thus, the approach has the potential to transcend the linear view of technical change and hence, puts new focus on the importance of the demand factor.
6. In mainstream economic theory innovation is, more or less explicitly, often assumed to be limited to process innovation. The NSI approach encompasses product technologies in its concept of innovation. Organisational innovations

41 Edquist (1997), see also Edquist and Hommen (1999).

may be included in the systems approach, though the current works have not analysed this aspect in a systematic way.

7. All the NSI approaches emphasize the role of institutions as central elements influencing innovation. However, the various contributors to the development of the approach do not mean the same thing when they use the term institution. It seems that it is used in two main senses: (1) ‘things that pattern behaviour’ like norms, rules and laws; and, (2) other formal structures with an explicit purpose, i.e., what is normally called organisations.
8. As mentioned above, the NSI approach is associated with various kinds of ambiguities, it is conceptually diffuse. These usually correspond to different definitions of systems of innovation, different perception of institutions, and undefined limits of the system in an operational way.
9. There are ‘hard core’ theories which are proven and not disputed, and there are formal models, conceptual frameworks useful for the generation of hypotheses and empirical generalizations. Nelson and Winter[42] distinguish between appreciative theorizing and formal theorizing in economics. The former tends to be closer to empirical substance and empirical work. It provides both interpretation and guidance for further exploration. Formal theorizing, on the other hand, is an abstract structure expressed in highly stylized form and set up to enable one to explore, find and check proposed logical connections. From this perspective, the NSI approach is a ‘conceptual framework’ which scholars and policy-makers consider to be useful for the analysis of innovation.

42 Nelson and Winter (1982)

Perhaps an additional, maybe obvious, common characteristic of the diverse approaches is that they are explicitly policy oriented. That is the main reason why they decide to put the boundaries of the system at the national level even though they recognise that doing so presents some problems to interpret for example the innovation dynamics of multinational corporations. However, this decision implies that the stress of the studies lies in the analysis of the national conditions, aimed at the creation of a fruitful environment for innovation, rather than in the abstract study of innovation itself.

Synthesizing, the NSI approach helps to stress the importance of the supra–national, national, regional and sectoral dimensions in determining the innovative behaviour of firms. This environment, in turn, influences the structure and interactions of industries, firms, the research subsystems and networks, the institutional framework and the diverse governments' policies. Policy making aimed at improving innovative performance should then take into account some particular characteristics of systems, such as the 'constitutive unity'[43] between element and relation. This implies that maintaining the NSI operation depends on stimulating the creativity of the agents through, simultaneously, improving the depth and quality of the connections. The different elements that constitute the system make complementary contributions to the innovation process by informal and formal relationships that facilitate knowledge flows. It has been suggested through the observation of various experiences, that networking —that is the establishment of semi–permanent relations between agents, seems to be the most adequate mechanism to allow such flows.

The NSI approach helps to identify the range of structural elements whose strength allows the successful competitive performance of national industries.

43 Within a system, there are no elements without relational connections or relations without elements. See Luhmann (1995).

However, research work about National Innovation Systems takes place on a fairly high level of aggregation and there remains a gap between the structural assessment and the detailed process involved in the unfolding and possible formation of competitive networks and industrial clusters. Additionally, NSI literature focuses mainly on dyadic relations; there are few empirical studies that address and describe regional or sectoral patterns of interaction between a broad variety of actors[44]. Finally, the NSI framework has been under construction mainly developed by academics and policy analysts during the last ten or fifteen years, but despite the initial Aalborg effort it could be argued that there is not a comprehensive theoretical work describing it. From the bulk of work produced within the framework or making reference to it, we can identify three main streams or paths of research: (i) attempts to develop from a theoretical or methodological point of view the general concept or associated notions, including the derived frameworks of regional and sectoral systems of innovation; (ii) the development of stand–alone or comparative studies with a heterogeneous methodological basis[45], mainly carried out under the auspices of international organisations such as the OECD or the EU; and (iii) combinations of the two previous approaches.

In a recent contribution, Lundvall et al[46] suggested four lines of research or challenges for the NSI concept: the deepening of the notion and its grounding in the concept of learning and competence building, the need to broaden the analysis of economic development, and to apply the concept to innovation policy. However, it could be useful to make some precisions to these ideas. Starting with the deepening of

44 Meeus et al (1999).

45 It is even surprising that the chapter by Edquist and Lundvall (1993) included in the book edited by Richard Nelson, makes little reference, methodologically speaking, to the Aalborg approach apart from the use of the concept of development blocks.

46 Lundvall et al, 2002

the notion there is the need to verify how well the innovation systems concept fits within general systems theory and how this approach could help to deepen our understanding of NSI; similarly, the links between evolutionary economics and the NSI framework should be revised to strengthen the theoretical background of the latter . This in turn could be very helpful to shed light on aspects concerning the definition and delimitation of elements and interactions within systems, the diverse levels of analysis which can be used and where to put the boundaries of the systems, and the generalisation of the notion to different levels of economic development. Secondly, there is the need to deepen several methodological issues, especially those concerned with the development of indicators to better reflect the flows (interactions and processes) of knowledge and resources (elements) within systems and its impact in the creation and diffusion of innovations[47]. Finally, there is the need to evaluate the impact of the notion on policy–making activities. This implies from our point of view, to revise the role of knowledge[48] and its reproduction and dissemination in the economic system and the role of national states to guarantee this process. Additionally, these efforts should assess whether the adoption of the systemic language and even the NSI concepts have led to the development of new and modified policy instruments, to the creation of new organisational structures and institutions, or to the combination of both, for the promotion of innovation activities at sectoral, regional and national levels.

DISCUSSION ON INNOVATION POLICY RATIONALES AND SYSTEMS OF INNOVATION

Models and theories are intellectual constructs that attempt to represent reality in order to understand it with certain degrees of accuracy and detail. These are built by

47 A similar problem was identified by Lundvall (1992) in his seminal work, but to this date NSI studies are based mainly in traditional economic indicators.

48 I prefer to use the more comprehensive concept of *knowledge* instead of the more elusive notion of 'learning'.

means of reducing the real complexity of particular phenomena to a simpler and understandable one, by means of making simplifying assumptions., but the more assumptions we make, the more simplified the model will be, i.e., increasing the number of assumptions is a way of reducing complexity, and in some circumstances, this procedure is very useful though it also reduces the accuracy of the model and the amount and quality of our knowledge; thus, the resulting knowledge will be as good as its underlying assumptions[49], and this should be evaluated carefully, since planning under simplified premises always has the risk of undesirable effects. During the process of planning and policy–making, for example, a model of the system in question is made in order to get some orientation into the system complexity. Subsequently, this simplified version is introduced into the system in a self–referential process that increases the capability of the system to be constrained[50] and for constructing order by reducing complexity[51].

Allen[52] suggests a set of assumptions that are helpful to describe and analyse industrial (innovation) processes as well as the economic models which are currently used to justify science, technology and innovation policies: first, a system and its environment are defined; secondly, rules for the classification of the components in the system are determined; thirdly, it is assumed that the components are either identical or have normally distributed properties about an average; fourthly, it is supposed that the system behaviour can be adequately described by the average of individual events or element properties; fifthly, the assumption that the system will naturally move to an equilibrium state is made.

49 See Allen (2001).

50 Interrelationships within a system work as constraints on the behaviour of the elements or subsystems involved as means to limit variety.

51 See Luhmann (1995).

52 Op. cit.

Neoclassical economics for example, makes use of the five assumptions to describe economic systems in terms of a static model with rigid rules for the properties and behaviour of the elements of the system. On the other extreme, evolutionary approaches of innovation make use of only the first two assumptions to describe economic systems as evolutionary complex systems. While the former has the advantages of its simplicity and the apparent possibility of looking at policies in terms of stationary states, before and after the decisions are made, it has the disadvantage of sweeping many details of the processes occurring in the system aside. On the other hand, the latter approaches have made significant advances in the understanding of the detailed process of innovation and the complex set of interactions that make it possible, but due to the complexity involved, the models are still incomplete or lack of sufficient formalisation, and the policy recommendations derived from them are fairly general and diffuse. There are in this case many more policy targets, but precisely due to the nature of the models involved, we have neither means to choose or to distribute resources among them, nor an efficient way to measure how these efforts have an impact on a particular innovative performance.

From a policy–making perspective, the main question is then “whether or not a simple enough description can be found that is still sufficiently realistic to be useful”[53], which in this case implies to assess the quality and usefulness of the knowledge we are obtaining with these models, the simplicity, effectiveness and efficiency concerning the implementation of the policies derived from them, and even the possible complementarities and contradictions that could appear if we decide to

53 Allen (2001, p344)

use a mixed approach[54]. In the following we shall focus on some concluding reflections on these issues to orient our future research work.

Table 1 synthesises some of the main features of the equilibrium and evolutionary models that we have been briefly discussing in this and some of the previous sections[55]:

Table 1 Main features of equilibrium and evolutionary rationales

	Equilibrium	Evolutionary
Main characteristics of underlying theories	Maximising behaviour Unique equilibrium Exogenous non explicit technology Non explicit technological change No explicit economic structure	Non–maximisation No unique equilibrium Endogenous and explicit technology Explicit technological change Structure is explicit
Policy action justification	Knowledge markets are imperfect • Indivisibilities • Uncertainty • Innapropriability	The system destroys the conditions for its reproduction Several subsystems (including the market) fail to reproduce and disseminate knowledge • Failures in infrastructure • Transition failures • Lock–in failures • Institutional failures
Bechmarks used or proposed	Interim efficiency[56] Paretto efficiency Best practices	No optimal allocation of resources Policy judgement (theory, measurement, subjective judgement)
Implementation problems	Imperfect information and feedback Government failure	System complexity Imperfect information and feedback Government failure
Incrementality tests	Narrow incrementality (the goal of a policy is achieved, and it could have not been achieved without the policy) Ideal incrementality (the goal of a policy is achieved, and it is an optimal solution)	Weak incrementality (the goal of a policy is achieved, independently if it could have been achieved without the policy)

It should be noted that both models have a systemic rationale, i.e., they are “a set of elements standing in interrelationship”[57] and they can be described hierarchically

54 Cf. Lipsey (1998).
55 Main sources: Metcalfe (1995a), Lipsey (1998), Hauknes & Nordgren, (1999) and Georghiou et al (2003)
56 See Holmstrom and Myerson (1983)
57 von Bertalanffy (1980).

by their unity or unities, elements, relations and boundaries[58]. But as mentioned above, the difference lies in the number of assumptions and restrictions we impose for the system to work, which in turn imply radically different properties and behaviours of the components and their interactions as well as different boundaries and hierarchies between systems and subsystems.

From this we can infer that the underlying rationale for policy action corresponds in both models to ‘system failures’, i.e., market failures are also system failures, but while the equilibrium approach sees policies as exogenous interventions to correct imperfections originated in the modelling limitations of the system, the evolutionary perspective with a wider and deeper understanding of reality sheds light to perceive that some of those alleged imperfections are in fact natural conditions of the process that is taking place. This in turn transforms policy action into endogenous control subsystems, responsible of making adaptive adjustments for the better operation of the whole system. From this we have a fundamental difference between a ‘fully informed’ planner identifying and implementing optimal solutions to be applied horizontally in the whole economy, and an ‘adapting planner’ fine–tuning diverse processes at various levels of the economic arena.

But despite the differences between perspectives, both models work with the same features or processes of the economic system: the opportunities, the incentives and the distribution of resources to innovate[59]. Thus, it seems that whether we use a simple or a complex explanation of the economic process there is a pervasive problem to solve, namely that knowledge has some particular properties which affect its reproduction and diffusion in economic terms. One perspective simply recognises a

58 In a similar way as stated above, the systems approach is an intellectual construct to understand reality.
59 Metcalfe (1995b)

failure in the system which will generally fail to produce the best possible allocation of resources for the reproduction and diffusion of knowledge. The other is able to explain that knowledge has become the most important input to the process and that some of its features are essential for the working of the economy, but that the dynamics of the system exhaust its own resources through the elimination of variety, and hence, this will hinder the generation and dissemination of new knowledge. In other words, the ultimate system failure in our economic system is the lack of capacity of the system to recursively regenerate —by means of its interactions— the network of processes that produced them[60].

Finally, from the previous reflection and despite the fact that the evolutionary–systemic approach has the potential to supersede the linear–science push vision of innovation[61] there seems that this pervasive problem around knowledge reproduction will favour a general trend towards supply–oriented policies. It also seems that the current literature has not paid enough attention to this fact and this implies that in practice, in one way or another, both rationales have prescribed mainly supply oriented policies. In addition, it could be said that the evolutionary–systemic approach has not been able yet to suggest policy measures or instruments significantly different from those which have been in use for several decades. An *a priori* perception would be that the practice of policy–making has been making use of the equilibrium rationale concerning the specific instruments to influence innovation activities on the one hand, and on the other , it has been relying on the systemic rationale to make changes to the institutional structure that manages those instruments. The in–depth study of these issues constitutes the core of our future research work.

60 See the notion of autopoiesis in Varela et al (1974)

61 Cf. Edquist & Hommen (1999).

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