Article

THE OECD SYSTEMIC MODEL OF SCIENCE AND INNOVATION POLICY

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ABSTRACT. There is currently, a broad diffusion of the notion of innovation systems in the innovation studies literature. Using an economic perspective, this article departs from a discussion of the origin and interpretations of this concept, and subsequently focuses on tracing back the influence of the systems approach in the inception of science and innovation policy. The analysis is made by means of deconstructing the OECD model of policies to verify its consistency with systems methods. It is concluded that the use of systems notions in innovation studies is not univocal.

INTRODUCTION

The notion of system has been broadly used in innovation policy studies,[1] particularly since the publication of diverse works using the concept of national system of innovation (NSI).[2] These have stressed the need to use a holistic approach to address the study of the production and diffusion of economically useful knowledge and suggest a general framework consisting in the decomposition of the economic system into the elements and interactions that constitute innovation processes. Despite having some problems, such as theoretical

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1 For the sake of simplicity, the term innovation policy is used throughout this article with the current meaning that synthesises science, technology and innovation policies.

2 See Christopher Freeman, Technology Policy and Economic Performance: Lessons from Japan (London: Pinter, 1987); Bengt-Åke Lundvall, National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning (London and New York: Pinter, 1992); and Richard R. Nelson, National Innovation Systems: A Comparative Analysis (New York and Oxford: Oxford University Press, 1993).

diffuseness,[3] the framework has had a surprising diffusion and some of its aspects have been either adopted by innumerable scholars, policy analysts politicians and international organisations, or adapted as departing point for similar approaches such as sectoral and regional systems of innovation and technological systems.[4] However, given the theoretical ambiguity of the notion this diffusion has implied different interpretations.

The origin of the use of the notion of systems associated with innovation studies can be found in the evolution of the concept of innovation.[5] Particularly, when interactive models of this process were developed in opposition to the dominant linear view and which implied also the participation of a broad group of agents in innovation processes. Andersen suggests that this association started in the works of several scholars related with Christopher Freeman and the Science Policy Research Unit of the University of Sussex (SPRU).[6] In this respect, we will

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[3] See Charles Edquist, 'Systems of Innovation: Perspectives and Challenges,' in Jan Fagerberg, David Mowery and Richard Nelson (ed.), The Oxford Handbook of Innovation (Oxford: Oxford University Press, 2005), 181–208.

[4] See S. Breschi and F. Malerba, 'Sectoral Innovation Systems: Technological Regimes, Schumpeterian Dynamics, and Spatial Boundaries,' in Charles Edquist (ed.), Systems of Innovation: Technologies, Institutions and Organizations (London and Washington: Pinter, 1997), 130–156; Bo Carlsson, 'Technological Systems and Economic Performance,' in Mark Dodgson and Roy Rothwell (ed.), The Handbook of Industrial Innovation (Aldershot: Edward Elgar, 1994), 13–24; and P. Cooke, M. Gomez Uranga and G. Etxebarria, 'Regional Systems of Innovation: Institutional and Organisational Dimensions', Research Policy 26 (1997), 475–491.

[5] Our discussion in this section is from the perspective of the economics of innovation. For a recent work focused from a social constructivist view of the origin of the NSI concept see Naubahar Sharif, 'Emergence and Development of the National Innovation Systems Concept', Research Policy 35 (5), (2006), 745–766. Nevertheless, there are some similarities between both approaches.

[6] See Esben Sloth Andersen, Evolutionary Economics: Post-Schumpterian Contributions (London: Pinter, 1994).

refer in future sections to an OECD study prepared by Keith Pavitt in the early 1970s where the notion of innovative system is used referring to the factors and interactions that make possible innovation processes. These interpretations are perhaps more related with notions such as social networks than with systems, since these latter have particular, more complex connotations than the simple interaction between components. Nevertheless, what is clear is that these early associations between system like notions and innovation implied the conceptualization of this phenomenon as a non-linear process involving the coordinated participation of a broad range of actors.

The subsequent use of the concept of systems of innovation, in the late 1980s and early 1990s, involved an extension of the network conceptualisation of the innovation process to include the role of institutions and to a certain extent some aspects of evolutionary economics. It has been extensively discussed that there is not a unified notion of systems of innovation,[7] since the main proponents corresponded to different research traditions, where

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[7] The classic reference in this respect is Charles Edquist, 'Systems of Innovation Approaches – Their Emergence and Characteristics,' in Charles Edquist (ed.), Systems of Innovation: Technologies, Institutions and Organizations (London and Washington: Pinter, 1997), 1–35. Another early analysis of these differences was made by Maureen McKelvey, 'How Do National Systems of Innovation Differ? A Critical Analysis of Porter, Freeman, Lundvall and Nelson,' in Geoffrey Martin Hodgson and Ernesto Screpanti (ed.), Rethinking Economics: Markets, Technology and Economic Evolution (Aldershot and Brookfield: Edward Elgar, 1991), 117–137. Subsequent works of the main proponents usually make reference to the differences between their frameworks, see Christopher Freeman, 'The National System of Innovation in Historical Perspective', Cambridge Journal of Economics 19 (1), (1995), 5–24; Christopher Freeman, 'Continental, National and Subnational Innovation Systems – Complementarity and Economic Growth', Research Policy 31 (2), (2002), 191–211; Bengt-Åke Lundvall, B. Johnson, E.S. Andersen, and B. Dalum, 'National Systems of Production, Innovation and Competence Building', Research Policy 31 (2), (2002), 213–231; and Richard R. Nelson and Katherine Nelson, 'Technology, Institutions, and Innovation Systems', Research Policy 31 (2), (2002), 265–272. See also Sharif, op. cit. note 5.

probably the common denominator was Schumpeter. However, apart from the similarities between approaches suggested by Edquist,[8] it seems that the main original interpretation was aimed at explaining national patterns of growth and economic development through the analysis of the interactions between the actors and institutions participating in innovation networks.

Linked with this primary objective, there was also an implicit or explicit policy orientation that is more clearly stated in the Aalborg version in terms of institutional learning.[9] It could be said that this original interpretation was an appreciative evolutionary framework to explain national innovative performance. Since its main structure consisted of actors, institutions, and relationships involved in innovation activities, from this probably followed the association that it was possible to refer to specific, national innovation systems, that is to say elements and interactions constituting systems at the national level.

Despite the policy orientation, none of the original approaches included an operational version of the systems of innovation approach. This has been mainly developed by the OECD, which explicitly adopted the notion since the late 1980s.[10] From this followed what can be called the generalized interpretation of the systems of innovation approach which implies that particular systems can be sufficiently described by enumerating the main components

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[8] Edquist, op. cit. note 3.

[9] See Bent Dalum, B. Johnson, and Bengt-Åke Lundvall, 'Public Policy in the Learning Society,' in Bengt-Åke Lundvall (ed.), National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning (London and New York: Pinter, 1992), 296–317.

[10] See Paul David and Dominique Foray, Accessing and Expanding the Science and Technology Knowledge Base. A Conceptual Framework for Comparing National Profiles in Systems of Learning and Innovation, (Paris: Organisation for Economic Co-operation and Development, 1994); and OECD, Technology and the Economy: The Key Relationships (Paris: Organisation for Economic Co-operation and Development, 1992).

involved in innovation processes and analysing some of their relationships. From the analysis of how these interactions shape successful innovation systems, either missing components and institutions or best institutional practices can be also identified as guides for international institutional learning. This generalized interpretation has been refined in several OECD reports[11] as well as in studies carried out by other international organisations such as the European Union,[12] and is usually the one used in the plethora of studies published in the literature that refer to innovation systems.

While the original and the generalized interpretations seem to be very similar, there are subtle theoretical differences that from the point of view of some of the original proponents are of considerable importance. These are mainly referred, firstly, to the limits of international institutional learning with regard to historically determined path dependency.[13] And, secondly, to the shift from allocation to innovation and from decision-making to learning.[14]

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11 Such as OECD, The OECD Jobs Study. Facts, Analysis, Strategies (Paris: Organisation for Economic Co-operation and Development, 1994); OECD, Managing National Innovation Systems (Paris: Organisation for Economic Co-operation and Development, 1999); and OECD, Dynamising National Innovation Systems (Paris: Organisation for Economic Co-operation and Development, 2002).

12 See Charles Edquist, Leif Hommen, Björn Johnson, Tarmo Lemola, Franco Malerba, Thomas Reiss and Keith Smith, The ISE Policy Statement – the Innovation Policy Implications of the 'Innovation Systems and European Integration' (ISE) Research Project (Linköping: European Commission, 1998); and Luc Soete and STRATA-ETAN Expert Group, Benchmarking National Research Policies: The Impact of RTD on Competitiveness and Employment (IRCE) (Brussels: European Commission, DG Research, 2002).

13 See Bengt-Åke Lundvall and Mark Tomlinson, 'Learning-by-Comparing: Reflections on the Use and Abuse of International Benchmarking,' in G. P. Sweeney and Six Countries Programme (ed.), Innovation, Economic Progress and the Quality of Life (Cheltenham: Edward Elgar, 2001), 120–136.

14 Esben Sloth Andersen, Bengt-Åke Lundvall and Henrik Sorrn-Friese, 'Editorial', Research Policy 31 (2002), 185–190; Bengt-Åke Lundvall, 'User-Producer Relationships, National Systems of Innovation and Internationalisation,' in Bengt-Åke Lundvall (ed.), National Systems of Innovation: Towards a Theory of

What these differences emphasize is the orientation of the systems of innovation approach as a theoretical structure to make detailed case studies aimed at identifying features of economic systems that *differentiate* one national system from another.

The existence of these interpretations suggests therefore, that an in-depth analysis of the systems of innovation framework from diverse points of view including that of the systems approach could be useful to revise the concept and to suggest a unified perspective. Our purpose for this article is to contribute in this direction by tracing back the influence of the systems approach in the genesis of science and innovation policies. Through the analysis of key OECD documents, we will attempt to deconstruct their implicit model of innovation policies and show that it included elements, structure and methods derived from the systems approach. In addition, we will show that an embryonic 'systemic view' close to the holistic perspective promoted by the current systems of innovation approaches, was already present since the early OECD documents of the 1960s.

BRIEF HISTORICAL ACCOUNT 1950S–1980S

In industrialized countries, besides the post-war efforts of diverse international organisations such as UNESCO, science policy received special attention by the Organisation for Economic Cooperation and Development (OECD) and its precursor the Organisation for European Economic Cooperation (OEEC). The origins of scientific activity in the OEEC can be traced to 1949 when its Council set up the Working Party No. 3 on scientific and technical information. This was constituted by senior representatives of applied research organisations of the members' governments and concluded that at that particular period of European reconstruction, when capital was scarce, '… scientific research and even technological

Innovation and Interactive Learning (London and New York: Pinter, 1992), 45–67; and Bengt-Åke Lundvall et al., op. cit. note 7.

innovation had little to offer immediately.[15] The main problem they identified concerned that of changing the attitude and performance of industry by a more rational or scientific approach to problems of industrial nature and efficiency in order to obtain a higher yield from the economy.

The group of scientists that worked on these recommendations launched the European Productivity Movement, which influenced the creation of the OEEC's Productivity Agency, a precursor of the Office of Scientific and Technical Personnel of the OECD, where the first programmes in science were developed. However, the Working Party No. 3 also recognised that a decade later research and technological innovation would become of great importance and for this reason experiments in international research cooperation, carried out on a voluntary basis should be initiated immediately.[16]

By 1959, discussions on science within the OEEC began to raise doubts concerning the effectiveness of the research effort of its member countries in relation to overall national and economic objectives. Therefore, the Secretary General of the Organisation invited Mr. Dana Wilgress, former Canadian ambassador to the OEEC and NATO, to undertake a study about the general situation and problems of the scientific organisations of the member countries. Mr. Wilgress visited most OEEC countries having discussions with ministers and senior science administrators and found a low level of awareness about the real potential of the application

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[15] Alexander King, 'Science in the OECD,' in OECD (ed.), Ministers Talk About Science: A Summary and Review of the First Ministerial Meeting on Science, October 1963 (Paris: Organisation for Economic Co-operation and Development, 1965), 17–24, p.17.

[16] Following this recommendation, experiments began in three areas – utilisation of tonnage oxygen in industry, generation of electricity by wind power and distillation for highly saline waters; chosen less for their intrinsic importance than as pilot examples to see whether a low-cost, flexible method of achieving cooperation could be worked out. See Alexander King, Science and Policy: The International Stimulus, (London and New York: Oxford University Press, 1974); and Alexander King, op. cit. note 15.

of science to specific needs and reluctance to abandon their research traditions and to adapt their educational systems to the emerging needs of science and technology. He produced confidential reports on the situation of each country and a general report in which he stressed the need of coherent policies to exploit the full potential of science for the benefit of European economy: 'The first thing should be for each country to draw up a national science policy.'[17] This was meant essentially as a resource investment policy, considering the need for a proper balance between fundamental and applied research, and which regarded science as the basis of technological innovation and economic growth. From his point of view, this national policy should also include international research cooperation.

Mr. Wilgress also recommended to strengthen the OEEC scientific programmes, and to supplement the existing committees of Applied Research and Scientific and Technical Personnel with a small high-level advisory group of scientists, which he conceived essentially as a science policy group. The report was favourably received by the OEEC and a few months later when the transformation of this into the OECD took place, and the function of science in the new organisation was again under discussion, its Secretary General appointed an ad hoc group, in the spirit of the Wilgress Report. The group was assigned the task of providing advice on policy issues of science and technology demanding the attention of governments, as well as on the long-term objectives of the OECD in the field. The ad hoc group, worked for about a year under the leadership of Pierre Piganiol, at that time chief scientist of the French government, and in turn produced the report Science and the policies of governments.[18]

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[17] Dana Wilgress Co-operation in Scientific and Technical Research, (Paris: OEEC, 1960), as quoted by Alexander King, op. cit. note 15.

[18] OECD, 'Science and the Policies of Governments. The Implications of Science and Technology for National and International Affairs,' in OECD (ed.), Ministers Talk About Science: A Summary and Review of the First Ministerial Meeting on Science, October 1963 (Paris: Organisation for Economic Co-operation and Development, 1965), 149–178. From now onwards we will refer to this as the Piganiol Report.

The main recommendations of the Piganiol Report included, firstly, that each government should consider setting up some central mechanism to discuss science policy, that is to say a National Science Office responsible for the formulation of a national policy for science; and secondly, a call to OECD to organize a meeting of ministers responsible for science policy in the member countries. Despite there was some opposition to the idea of holding a meeting to discuss science within an organisation essentially of economic nature, the First Ministerial Meeting took place in October 1963, having as main background document the Piganiol Report. During the decade following the publication of that report, most member countries created formal bodies to deal with national science policy and many of them appointed ministers directly responsible for science and technology. The changes in the economic environment and the rapid evolution of science and technology as well as the emergence of unexpected effects of these activities during the following decades, led the OECD Secretariat to set up subsequent task forces in the early 1970s and 1980, to re-evaluate the position of the organisation towards science policy. The recommendations of these ad hoc groups are contained in the documents Science, growth and society, also known as the Brooks Report,[19] and Technical change and economic policy.[20]

CHARACTERISTICS OF THE MODEL

The aforementioned reports, constitute the backbone of the OECD systemic model of science and innovation policies and were supplemented, among other activities, with the following three crucial instruments: first, establishing a homogeneous system of science and innovation performance measures including criteria for the collection of statistical information

[19] OECD, Science Growth and Society: A New Perspective. Report of the Secretary-General's Ad Hoc Group on New Concepts of Science Policy (Paris: Organisation for Economic Co-operation and Development, 1971). From now onwards we will refer to this as the Brooks Report.

[20] OECD, Technical Change and Economic Policy: Science and Technology in the New Economic and Social Context (Paris: The OECD, 1980). From now onwards we will refer to this as the Delapalme Report.

concerning these activities.[21] Second, creating a system to evaluate national science and innovation policies. Member countries have been able to request under the scheme an examination of their policies and support structure for science and innovation, carried out by teams of experts, as a means to obtain general recommendations based on international experience and the successes and failures of the experiments of other countries:[22]

> 'The admirable aim of these reviews […] was to produce a friendly but independent and critical assessment of each country's performance by an international comparative yardstick.'[23]

Finally, the OECD has not only been concerned with the general structure of science and innovation policies at the national level, but it has also been involved in the organisation of innumerable conferences of experts and in the elaboration of several reports and background documents discussing diverse theoretical, methodological and technical issues concerning science, technology and innovation.

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21 First with criteria to define and measure scientific and technological research activities, contained in the document referred to as the Frascati Manual, whose first version was published in 1963, see OECD, Frascati Manual 2002: The Measurement of Scientific and Technological Activities: Proposed Standard Practice for Surveys on Research and Experimental Development (Paris: Organisation for Economic Co-operation and Development, 2002). Later, the document known as Oslo Manual was prepared to establish more accurate criteria to identify innovative activities, see OECD and European Commission, The Measurement of Scientific and Technological Activities: Proposed Guidelines for Collecting and Interpreting Technological Innovation Data: Oslo Manual (Paris: Organisation for Economic Co-operation and Development and European Commission, 1997).

22 Initially these reports were called Reviews of National Science Policy, later they were substituted by Country Reports of Innovation. A thorough analysis of the former can be found in Luisa Henriques, Portugal as a Research Laboratory for the National Innovation System Concept, PhD Thesis, Ecole des Mines de Paris, 2005, chapter 3.

23 Christopher Freeman, 'The National System of Innovation in Historical Perspective', Cambridge Journal of Economics 19 (1), (1995), 5–24, p.10.

There are at least three reasons why we consider that the OECD has been promoting a systemic model of science and innovation policies: first, we have to take into account that systems analysis was widely diffused during the 1960s and that its methods had an especial impact in policymaking activities in several areas. The Brooks Report makes an explicit reference to this influence: 'The second phase [of the political climate of science] extended from about 1961 to 1967 and was characterised by the gradual emergence of economists and systems analysts as significant influences in science policy.'[24] Therefore, it is not surprising that the general approach to science policy that was adopted since the Piganiol Report and in the subsequent main reports was consistent with the basic systems analysis methodology. This general model includes: (i) identification of the ultimate goals and performance measures of the system; (ii) analysis of the environment and fixed constraints; (iii) identification of the system's components; (iv) analysis of their resources; and, (v) proposal of a structure responsible for the management of the system.[25]

Secondly, from the 1960s to the early 1980s, the notion of *Research System* was broadly used by the OECD or by groups of experts discussing national policies for science.[26] The concept

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[24] OECD, Brooks Report, p. 39; see also Jean Jacques Salomon, 'Science Policy Studies and the Development of Science Policy,' in Ina Spiegel-Rösing and Derek de Solla-Price (ed.), Science, Technology and Society. A Cross-Disciplinary Perspective (London and Beverly Hills: SAGE Publishers, 1977), 43–70. For particular applications of systems analysis see OECD, Analytical Methods in Government Science Policy: An Evaluation, (Paris and London: Organisation for Economic Co-operation and Development and HMSO, 1972).

[25] See Charles West Churchman, The Systems Approach (New York: Delacorte Press, 1968), pp. 28–47.

[26] See for example the work of R.L. Ackoff, 'Operational Research and National Science Policy,' in Anthony V.S. De Reuck, Maurice Goldsmith and Julie Knight (ed.), Decision Making in National Science Policy. [Proceedings of] a Ciba Foundation and Science of Science Foundation Symposium (London: J. & A. Churchill Ltd., 1968), 84–98; which includes a model that comprises the whole national system within which the science and technology subsystem operates.

was used to denote a continuous system, defined by a chain of formal and informal links between different organisations, that is to say the non-linear interactions between the science and technology sphere as well as between this and other areas within the national economy, such as defence, industry, health, social welfare and education:[27]

> The scientific effort of a country can be represented by one such sub-system, which overlaps all the other sub-systems in a three dimensional model. There is indeed at the centre of the science sub-system an area which does not cover any other national sub-system, although it possesses an important and diffuse interface with the education subsystem. This is the area of fundamental research, which is the reproductive mechanism of the science sub-system and essential for the maintenance and constant regeneration of the whole.'[28]

Later, in 1971, Keith Pavitt introduced the notion of innovative system in the report The Conditions for Success in Technological Innovation,[29] referring to the factors and interactions that make possible the innovation process. While discussing the methodological framework of the report, Pavitt mentioned the possibility of addressing the process of technological innovation 'as a system of creating, coupling, transfer and use of information.'[30] However,

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27 See Anthony V.S. De Reuck et al., op.cit. note 26; Alexander King, Science and Policy: The International Stimulus, (London; New York: Oxford University Press, 1974); OECD, Problems of Science Policy: Seminar Held at Jouyen-Josas (France), 19th–25th February 1967 (Paris and London: Organisation for Economic Co-operation & Development and HMSO, 1968); OECD, Delapalme Report; and Jean Jacques Salomon, Gilbert Caty and OECD, The Research System: Comparative Survey of the Organisation and Financing of Fundamental Research (Paris and London: Organisation for Economic Co-operation and Development and HMSO, 1972).

28 Alexander King, op. cit. note 27, p.76.

29 OECD, The Conditions for Success in Technological Innovation (Paris: Organisation for Economic Co-operation & Development, 1971).

30 Ibid., p. 22.

given the complexity of the model involved and the lack of empirical information, a simpler approach was chosen, one that assumed:

> '… that technological innovation always requires the existence of three factors: first, a base of scientific and/or technological knowledge; second, an economic or social demand; third, a coupling agent which transforms the scientific and/or technological knowledge into goods and services which satisfy the economic or social demand.'[31]

Thirdly, despite the relative dominance of a linear, science-push model of innovation which is present in the majority of the literature and discussions about science policy, there are several references in the OECD reports that reveal an embryonic notion concerning the network structure of the innovation process as well as the systemic nature of policy-making within a national context. Besides the aforementioned study by Pavitt, the Piganiol, the Brooks and the Delapalme reports also include such types of notions. The former had naturally, a more limited view, reflecting the belief that the simple advancement of scientific knowledge would yield benefits in several areas of the economy and society. Nevertheless, it recognised the need to coordinate diverse spheres of national policy in order to obtain better general results from the efforts devoted to science and technology:

> 'There is a great need for studies of the several fields and ways in which science and policy interact, and there is a need above all for a continuing and intimate working relationship between officials responsible for science policy and other policy makers. Only thus will governments be able to take maximum advantage of the opportunities offered by scientific advance, and to insure against policies that may be inadequate to a world that technology changes from day to day.'[32]

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[31] Ibid.

[32] OECD, Piganiol Report, p. 164.

There is also in the same section of the report, an explicit mention to the benefits that scientific knowledge could gain thanks to its interactions with other activities and areas of knowledge:

> ‘The scientific enterprise itself can only benefit from enhancement of the enterprise of transfer. […] That source remains indispensable, but can now be supplemented by the added stimulus that comes from putting knowledge to work. This is the phenomenon of feedback. Wrestling with problems of formulating policies in disparate fields that take maximum advantage of scientific opportunities can in turn suggest still newer opportunities, as yet beyond the ken of science, in the form of further ideas for basic inquiry, more effective methods and institutions for research and development, and widened educational horizons.’[33]

The Brooks report reflects the ideas of a period of relative disappointment regarding the promises of science and technology and of preoccupation because of the unexpected by-products of these activities. It also criticised the naïve period concerning the understanding of the relationship between science and the economy, which had characterised the previous decade of science policies. The ideas contained in the document have undoubtedly superseded the linear model of innovation as can be inferred from the following quotations:

> ‘… building up scientific capabilities was no doubt right, but basing it on the implicit assumption that research and development expenditures necessarily mark a directly proportional contribution to growth was unwarranted. This is not to say that R&D does not contribute to growth; it must certainly does, but this relationship has to be seen in the framework of a more complex process whereby what accounts for growth is in fact total innovation, i.e. the sums of original and imported innovation and of the funds spent on probing

33 Ibid., p. 167.

> the market for new products, ironing out production bugs, and achieving adequate reliability in the commercial product.'[34]

And:

> 'All scientific and technological activities from 'pure' research to the development of prototypes can be regarded as a continuum within which meaningful lines of demarcation cannot be drawn, even though different policies are appropriate at different points along the continuum.'
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> 'However, innovation does not result from a linear sequence passing through all the stages of this continuum, automatically converting new knowledge into new applications.'[35]

In addition, a systemic view of policymaking is embedded in all the report and it is clearly synthesised in the letter of transmittal that Harvey Brooks addressed to the Secretary-General of the OECD presenting the report of the ad hoc group:

> 'The most important conclusion of our Committee is that the new orientation of our societies towards the qualitative aspects of growth and towards broader concepts of welfare will require a much closer integration of science policy with the totality of economic and social policy, especially in relation to the long range human objectives of economic development.'
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> 'The concept of science policy as a discrete and isolable element of government policy will tend to be replaced by a much broader view, one in which there is a close feedback relationship between technological opportunities and social goals, each being considered in the light of the other.'[36]

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34 OECD, Brooks Report, pp. 41–42.

35 Ibid., p. 70.

36 Ibid ., pp. 7–8.

Finally, the Delapalme Report, which corresponds to a period of great concern due to the economic turmoil characterised by the energy crisis and persistent inflation and unemployment, presents clearer systemic notions of science, innovation and policymaking. On the one hand, the report is almost entirely focused on innovation and its potential effects in the areas of economic concern such as productivity, inflation and employment. Innovation is also perceived as a process resulting from the interaction of a series of activities centred in industrial firms and where scientific research and technology development are just one component, though an important one, of a complex set of agents and interactions. On the other hand, the policy recommendations of the report call for better integration between science, technology and economic policies and include a broader range of support mechanisms than those traditionally oriented to the research domain:

> '… and one of the main objectives of government policy must be to create a framework in which market incentives stimulate the innovative capacity and performance of firms. However, a government policy of simply letting good firms succeed and bad firms fail is by itself likely to be painful and incomplete. A strong national capacity for innovation depends critically on deliberate government intervention in industry with regard to education and training as well as R&D, technology transfer and other supporting services.'[37]

In what follows we will focus our attention on the methodological structure of the OECD model of science and innovation policy. We will mainly use for this analysis the three key science and technology policy reports produced by OECD ad hoc groups from the 1960s to the 1980s. However, we will put special emphasis in the Piganiol Report and to a certain extent in the background documents of the First Ministerial Meeting of Science, to show that the systems approach was present since 1963. Although the terms of research, science and innovation systems were used in different documents throughout the years, the OECD never

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[37] OECD, Delapalme Report, p. 99.

used explicitly those concepts to refer to its own system of policies. However, we will show that the underlying structure of the OECD approach reveals its nature as a system of science and innovation policies that the organisation promoted among its members.

OVERALL OBJECTIVES AND PERFORMANCE MEASURES OF THE SYSTEM

There is general agreement in the literature that the ultimate objective of science (and innovation) policy is twofold. On the one hand, it attempts to provide the means for a continuous growth of the social knowledge base. This objective has been usually interpreted in terms of the enhancement and extension of basic and applied research that in turn will increase the social pool of knowledge. On the other hand, a parallel goal of science policy is to make the most of the positive effects of the scientific and technological knowledge that a society generates, especially in terms of wealth creation and economic growth.

> 'Maximum exploitation of scientific opportunities requires programmes that combine concern for the growth of science itself and provision for the rapid, deliberate application of its fruits to human welfare. That is the substance of science policy in the full sense, as denoting consideration of the interactions of science with policy in all fields.'[38]

There was obviously a wide range of interpretations, especially during the 1960s and early 1970s, concerning the main focus of science policy and in particular about the definition of what was covered and what were the differences between scientific and technological research. However, as we have discussed above, since the Brooks Report the position adopted by the OECD groups of experts was systemic in the sense that all the areas along the research continuum should be attended and that the links and cross-fertilisation between them, were crucial both for the generation of innovations and for the advancement of science and technology:

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[38] OECD, Piganiol Report, p. 160.

> ‘This process of reciprocal enrichment [of science and technology] cannot be minutely organized. It can be effectively expedited only by breaking down the mental, social, and political barriers to exchange. It is particularly between academic, industrial, and governmental scientific institutions that effective interlocking should encourage the circulation of ideas, people and results.’[39]

The evolution of the ultimate goals of science and innovation policies has to be analysed against the context of the multiple factors, including the policy cultures suggested by Elzinga and Jamison,[40] that determine the overall national priorities. What is evident is that the initial version of the OECD model was aimed at developing science and fundamental research because there was evidence of their social and economic implications. In contrast, the last version of the model in the period we are analysing was explicitly aimed at reorienting ‘the system for generating technical advance’[41] and industrial innovation as means to contribute in the solution of acute economic problems and to achieve this objective the support of scientific and technological research had special importance among other measures.

A supplementary objective of science policy within the OECD that was made explicit since the Piganiol Report concerned the need to increase international cooperation, particularly for the development of science. In addition, it was clear that this collaboration was also understood in terms of the role of the organisation in the exchange of experiences concerning science policy and in the diffusion and relative harmonisation of policies at international level.

One of the crucial aspects of planning and systems design correspond to the definition of performance measures for the system in question, since these are fundamental for monitoring

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[39] OECD, Brooks Report, p. 71.

[40] Aant Elzinga and Andrew Jamison, 'Changing Policy Agendas in Science and Technology,' in Sheila Jasanoff, James C Petersen, Trevor Pinch and Gerald E Markle (ed.), Handbook of Science and Technology Studies (Thousand Oaks and London: Sage Publications, 1995), 572–597.

[41] OECD, Delapalme Report, p. 94.

the operation of the system and to implement the necessary corrective measures to achieve the expected results. In the case of the OECD model of science and innovation policy this aspect was originally interpreted as the need of data, comparable across nations, on human resources and expenditures devoted to scientific research and technological development:

> 'Informed policy decisions […] must be based on accurate information about the extent and forms of investment in research, technological development and scientific education.'[42]

Therefore, a group of experts worked in parallel to the elaboration of the Piganiol Report in the first version of a standard for the collection of research and development statistics and by June 1963, it produced what became to be known as the Frascati Manual.[43] During the years, in part due to the increasing complexity of innovative activities and the need of accurate indicators and in part due to the evolution of the notions concerning R&D and innovation, the original standard has evolved significantly in extension and content and has given rise to a series of other specific manuals. The current 'Frascati Family' includes separate manuals on research and development (Frascati Manual), innovation (Oslo Manual), human resources (Canberra Manual) and technological balance of payment and patents as science and technology indicators. The establishment of performance measures is not only intended at monitoring the particular development of certain activities, but is also a means to redirect and shape the activities under scrutiny. Thus, in this way the OECD not only promoted the structuring of science, technology and innovation institutions in its member countries, as we shall see below, but it also provided a guidance mechanism embedded in measures of

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[42] OECD, Piganiol Report, p.163.

[43] From a different perspective to our line of arguments, a recent issue of Minerva, vol. 44 (2), The Studiengruppe für Systemforschung, makes reference to the influence of the systems approach in the early development of science policy studies in Europe. Specifically, there is a reference of this influence in the making of the Frascati Manual; see Helmut Krauch, 'Beginning Science Policy Research in Europe: The Studiengruppe Für Systemforschung, 1957–1973', Minerva 44 (2), (2006), 131–142.

performance. These have undoubtedly influenced national policies, some times by creating awareness of the lack of certain activities that could supplement national policies, other times by establishing best practices regarding levels and proportions of expenditures and human resources as well as levels of output in specific indicators such as patents or scientific publications:

> ‘Academic research on invention and innovation had amply demonstrated that many factors were important for innovative success other than R&D. However, the practical difficulties of incorporating these factors in international comparisons were very great. ‘League table’ comparisons of R&D were much easier and more influential.’[44]

THE SYSTEM’S ENVIRONMENT

The OECD model implies the consideration of at least three levels of environmental conditions surrounding the research (and innovation) system. First, there was since the early documents, a clear determination of other subsystems within the nation with which the research system interacts in a reciprocal way. These elements were understood as constraints of different degrees of importance, but it was possible to influence them both by means of horizontal policy coordination and by the expected medium-term effects of scientific and technological activity.

> ‘Science policy is moreover but an aspect of over-all national policy, and cannot be formulated in isolation. Plans to satisfy manpower needs, for example, cannot be made except in relation to educational policies and technological objectives. Government investment in research must be decided upon in the light of the over-all national budget and of the extent and kind of research being conducted in the private sector, and must take account of the relative economic advantages of alternative technological opportunities. Development decisions must be made in the context of such expected social consequences as temporary unemployment, labour mobility,

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[44] Christopher Freeman, op. cit. note 23, p.10.

> and new needs for job retraining. This complexity imposes upon a nation a formidable yet essential policy task.'[45]

The Piganiol Report included the following fields of national policy that were considered relevant for science policy: economic and social policies, education, military, foreign and aid policies as well as those related to the transfer and application of knowledge to industry. Secondly, the general economic environment where scientific and technological activities take place was also considered. As mentioned earlier, the analysis of economic factors has always had a prominent role in the configuration of the OECD model of science and innovation policy and as the knowledge about these relationships evolved, the characteristics of the model became more complex. This level was not only perceived as the target where the benefits of science and technology were expected, but also as a set of rules governing the allocation of resources for scientific and technological activities:

> 'Science and technology policies are not confined to creating a favourable environment for the development of research and of institutions which produce and disseminate knowledge. They also seek to ensure that research and development contribute to economic, social and political objectives. In this sense, the allocation of resources and the orientation of research and development are the instruments of policies which affect not only government research but also the conditions under which all scientific and technological activities, including those in the private sector, contribute to the achievement of national goals.'

> 'The system of research and innovation is not isolated from the social system as a whole: sooner or later, it both contributes to and is influenced by changes within society.'[46]

Given the nature of the OECD as an institution essentially concerned with economic progress, it is not surprising that these aspects received special attention. However, it was recognised

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45 OECD, Piganiol Report, p.161–62.

46 OECD, Delapalme Report, p. 12.

that the knowledge about the relationships between science, technology and economic growth was insufficient: ‘Science and technology have always, of course, influenced economic growth, but this influence has generally been assumed rather than accounted for explicitly by traditional theory.’[47] Therefore, the organisation took a very active role in the organisation of conferences and seminars to increase the knowledge on this area and undoubtedly was influential in the creation of mechanisms for the study and diffusion of topics related with science policy.[48]

The international economic and scientific environments constitute the final level of concern of the OECD system of policies for science and innovation. This dimension received special attention since the Piganiol Report, which devoted one of its sections to science and international affairs. In it, the main message consisted in a call to increase international cooperation in scientific activities and at the same time pointing out the need to join national efforts and initiatives towards an international science policy, understood as ‘policy guidance in international scientific activities.’[49] This international cooperation also included the role of the OECD in assisting countries in the process of development ‘to use science and technology as one means of achieving more rapid economic and social progress.’[50] Years later, the

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[47] Ibid., p. 159.

[48] Such as the research centres created in Sussex (SPRU) and Lund (See Jean Jacques Salomon, 'Science Policy Studies and the Development of Science Policy,' in Ina Spiegel-Rösing and Derek de Solla-Price (ed.), Science, Technology and Society. A Cross-Disciplinary Perspective (London and Beverly Hills: SAGE Publishers, 1977), 43–70, p.53) as well as the journals Minerva and Research Policy. It is not surprising then, that many of the leading authors in the field of science and innovation policy, such as J.J. Salomon, Christopher Freeman, Richard Nelson, Keith Pavitt, Luc Soete and Bengt-Åke Lundvall among others, have had different types of relationships with the OECD and its task forces.

[49] OECD, Piganiol Report, p. 174.

[50] Christopher Freeman, Raymond Poignant and Ingvar Svennilson, 'Science, Economic Growth, and Government Policy,' in OECD (ed.), Ministers Talk About Science: A Summary and Review of the First

Brooks Report was evidencing the doubts that had risen in different countries concerning the benefits of international scientific cooperation and suggesting a revision of these issues. It also called for attention on the need to increase the understanding of the role and effects of multinational companies; to keep close observation of the effects of science and technology on environmental problems; and to include in national science policies the issue of aid for scientific and technological development in developing countries. In contrast, the Delapalme Report, partly due to the prevailing economic conditions mentioned earlier, included a deeper analysis of the relationships between science, innovation and the international economy, but focused its recommendations towards the achievement of national competitiveness.

THE COMPONENTS OF THE SYSTEM

The OECD model has used, especially in its earlier versions, a functional definition of components, more in accordance with the methods of systems analysis that define components by their mission or functions. The conceptualisation of a research system that has been mentioned earlier, derives precisely from this approach. Thus, the main functions of this corresponded to the different types of basic and applied research, and experimental development.[51] These missions in turn, could be performed by diverse agents, mainly public and private research laboratories and universities, although there was a clear trend to consider that basic research was more likely to be performed at universities. In addition, despite recognising that other national subsystems were responsible of a series of activities interacting with that of research, special attention was paid to the relationships between this

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Ministerial Meeting on Science, October 1963 (Paris: Organisation for Economic Co-operation and Development, 1965), 95–119, p. 119.

51 The use of the concept of experimental development did not appear in the first version of the Frascati Manual, but was included in its second edition in 1970.

and the areas of economic policy that included the functions performed by the industrial sector and education:[52]

> '… long-term economic planning […] must provide for allocation of resources to encourage the growth of science and technology, consider science-induced changes in industrial structures, and plan for a continuing search of basic science for innovation.'[53]

The Brooks and Delapalme reports devoted much more emphasis to the characteristics and problems of the industrial sector as the main responsible of the function of innovation, as well as a clearer vision about the forms of interaction with the research system. The relationships with education were perceived not only in terms of the provision of qualified human resources for basic research, but also in terms of the need to reformulate the system of education in order to better respond to the changes generated by science and technology. These included the need to train and retrain, scientific researchers as well as industrial personnel in new areas of science and technology:

> 'Specific points at which science touches educational policy include the effect on curriculums [sic] of rapidly accumulating new subject matter, the requirement to develop the new kinds of specialists demanded by large-scale and complex modern technologies, and the need to continue education of the adult population throughout life if it is to remain sophisticated and politically responsible. Allied problems of manpower policy include the responsibility to anticipate future needs for trained manpower, and to provide mid-career retraining for a highly mobile labour force and for professional scientists and engineers who are increasingly finding that specialities in which they were initially trained are shorter-lived than they.'[54]

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52 Consider also the notion of innovative system discussed above.

53 OECD, Piganiol Report, p. 164.

54 OECD, Piganiol Report, p. 166. On this regard see also OECD, Brooks Report, pp. 71–74.

Another subsystem that is vaguely mentioned in the Piganiol Report, but not in the background documents for the First Ministerial Meeting of Science and in the subsequent reports of the 1970s and 1980s, is that responsible for the transfer of scientific knowledge to the areas of application. However, even in the earlier documents more emphasis is given to the problem of how to engage the industrial sector in innovative endeavours, covering the whole range of activities from research to commercialisation, through a series of measures to motivate investment and cooperative research.

> ‘There are in addition a host of problems relating to science organisation and management that fall within the purview of policy. There is often a need to encourage increased industrial expenditures on research by means of tax or other incentives, and to incorporate this effort in the over-all fabric of the nation’s research. The research contract as a new form of government-industry scientific co-operation needs study and refinement. Mechanisms may be necessary to bring new knowledge to experimental demonstration pending industrial interest in commercial exploitation.’ [55]

THE SYSTEM RESOURCES

Resources are the means that the system uses to do its jobs and opposed to the environment these are things that the system can change and use to its own advantage. In the case of the OECD system of policies, resources are mainly identified in terms of funds to finance research activities and infrastructure as well as scientific and technical human resources. The links that the organisation urged to establish between science and innovation policy and education policy to satisfy the demands of the research system have already been mentioned. The issue of allocation of financial resources to R&D, constitutes, on the other hand, one of the core elements of science and innovation policies.

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55 OECD, Piganiol Report, p. 162.

To a certain extent it could be said that science policy was the fundamental mechanism devised to cope with the market failures affecting scientific research and innovation. In the Piganiol Report, there is an implicit mention in several sections of the document concerning the inadequacies of the market mechanism to allocate resources to research. This need was perceived not only in terms of providing sufficient funds but also in identifying the most promising areas where these should be allocated. The background document Science, economic growth and government policy, presented in the First Ministerial Meeting of Science,[56] explained in detail the nature and sources of those market failures in terms of the familiar problems associated with uncertainty, externalities and inappropriability,[57] and concluded that:

> 'Governments must inevitably assume responsibility for science. They already contribute a large part of the funds for research and development in most countries, and they are in a unique position to take an over-all and long-term view. The inadequacies of the market mechanism and the competing claims for R and D resources inevitably draw governments into making decisions on the allocation of these resources and thus virtually determining the broad outline of government science policy.'[58]

Therefore, it was evident that the main task of science and innovation policy was to develop criteria for decision making and coordination between competing strands of research interests: from those related to the development of science per se, or the need to contribute to the solution of social problems, to the defence and military needs and the promotion of economic growth. Priority setting, made particularly in the light of long-term national goals, became one of the crucial concerns of science policy. In this respect, the position of the OECD

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[56] Which was a direct result of the Piganiol Report.

[57] See Christopher Freeman et al. op.cit. note 50, pp. 101–105.

[58] Ibid., p. 105.

was primarily to stress the need of developing mechanisms for priority setting and to provide information about alternative ways to do this, rather than suggesting specific methods to be adopted by countries. Thus, the topic received special attention in seminars and conferences and specialised reports were elaborated by experts in the subject.[59]

Another instrument associated with planning, establishing priorities and policy implementation was the national research budget. This was perceived as beneficial for several reasons: (i) to manage the overall sum and distribution of public resources devoted to research; (ii) to shield public investment in science in the face of budgetary restrictions; (iii) to act as a priority setting and monitoring instrument; and (iv) to help in the parliamentary discussions regarding national plans and strategies for science and economic growth.[60] The setting up of the national research budget was seen not only as the result of adding up the needs of diverse agencies and research performers, but of a careful process of negotiation in the context of national priorities and monitoring of current activities. This mechanism was not explicitly mentioned in the main science policy reports, but was actively promoted through the specific national reviews of science policy carried out by the OECD's experts.[61]

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59 See for example: Harvey Brooks, 'Can Science Be Planned?' in OECD (ed.), Problems of Science Policy: Seminar Held at Jouyen-Josas (France), 19th–25th February 1967 (Paris and London: Organisation for Economic Co-operation and Development and HMSO, 1968), 97–112; Erich Jantsch, Technological Forecasting in Perspective. A Framework for Technological Forecasting, Its Technique and Organisation. A Description of Activities and an Annotated Bibliography (Paris: Organisation for Economic Co-operation and Development, 1967); Erich Jantsch, 'Technological Forecasting – a Tool for a Dynamic Science Policy,' in OECD (ed.), op. cit. in this note, 113–123.; OECD, Analytical Methods in Government Science Policy: An Evaluation, Science Policy Studies (Paris and London: Organisation for Economic Co-operation and Development and HMSO, 1972); and J. Spaey, 'The Problem of Choice,' in OECD (ed.), op. cit. in this note, 127–134.

60 See Luisa Henriques, op. cit. note 22, chapter 3.

61 Ibid.

The Management of the System

Finally, the last consideration concerning the design of a system corresponds to the entity in charge of the management of its operation. This body is responsible of the planning activities and needs continuous monitoring of the overall performance of the system to determine if the actions taken are contributing to the achievement of the ultimate objectives. Consequently, if problems or deviations are detected, it must introduce corrective measures to reorient activities towards the fulfilment of the goals of the system. The OECD model included since the Piganiol Report a clear definition of these functions in the form of a National Science Office. This would be responsible of: (i) the formulation of the national policy for science; (ii) the coordination of the various scientific activities of the country; and, (iii) the horizontal integration of science policy with other areas of national policy. The type of structure suggested by the report was not exactly a science ministry, but rather an advisory body with influence across the major government departments that had scientific research activities among their responsibilities. However, it was clear that this office should be located and have influence at the highest levels of government organisation.[62]

The report was also emphatic on the fact that each country should design this advisory body according to its own political history, institutional structure, tradition and the nature, characteristics and complexity of its problems. Therefore, a generic description of such body was provided in the report, including its size and composition, responsibilities, scope and duties. These latter were conceived of two general types, information gathering as well as advisory and coordination.

Regarding the specific policy measures to implement the national plans, during the First Ministerial Meeting on Science, in the part devoted to the analysis of science and economic growth, policy instruments were reviewed concerning: the generation of knowledge,

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[62] See OECD, Piganiol Report, pp. 167–171.

including the provision of qualified human resources; international cooperation; and, promoting the involvement of the business sector in research and innovation activities. A few years later, the Brooks Report pointed out the need for further interventions in the operation of the market economy:

> 'Such interventions may take three forms. The first is the alteration of the ground rules and incentives under which the market operates by such devices as taxes, subsidies, and judicial actions to internalise social costs. The second is regulations and standards in relation to such matters as safety, pollution and use of land or other scarce common resources. The third is direct economic activities of government deemed to be sufficiently in the general public interest to warrant supplementing private activities beyond the level that market forces alone would generate. These interventions will affect the allocation of investments and the direction of innovation.'[63]

In sum, the basic policy tool-kit suggested by the OECD since the 1960s included the instruments shown in table 1.

[INSERT TABLE 1 ABOUT HERE]

CONCLUSIONS

The main argument of this article lies on a twofold perspective concerning the use of the systems approach in innovation policy studies. What we have called the original systems of innovation interpretations, make use of system like notions only to represent the operation of certain parts of the economy.[64] In contrast, our interpretation implies that policies are shaped to constitute a system and at the same time that a systemic model of reality has been used in

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63 OECD, Brooks Report, p. 89.

64 It is debatable however, whether these interpretations are genuinely systemic or they merely use some notions as labels or metaphors. For a detailed analysis of this issue see chapters 4 and 6 in Roberto E Lopez-Martinez, A Systems Approach to Innovation Policy, PhD Thesis, The University of Manchester, 2006.

the design of the system of policies. Our analysis of key OECD documents reveals the crucial role played by this organisation in the design and diffusion of such a system.

We have shown that it is possible to deconstruct the OECD model to display the consistency of its structure with systems methods, particularly with systems analysis. Simultaneously, we have also discussed that an embryonic version of the current perspective of decomposing economic processes into elements and interactions participating in innovation processes has been present since the early OECD documents. This version has obviously evolved, for its first incarnation implied an almost linear relationship between science, technology, and innovation. Nevertheless, by the early 1970s, this perception started to change and it is clear that the OECD was gradually adopting a non-linear, interactive approach in this regard.

One of the implications of our work is that the current interpretations of innovation systems discussed in the introduction correspond to two different, though interlinked currents of thought. We suggest that the origin of these, can be found in the OECD system of policies that has been discussed and whose theoretical background is heavily but not completely based on orthodox economics.[65] This, in turn, influenced the development of the original interpretations, which correspond to theoretical and methodological efforts to supplement innovation theory, built from neo-Schumpeterian economics perspectives. Subsequently, the OECD absorbed some elements and terminology of the latter and revised its system of policies generating the generalized interpretation of systems of innovation. From this follows that the use of terms such as system and systemic in the context of innovation studies is not univocal as the advocates of systems of innovation approaches suggest. Particularly since this use is not only associated with an interactive model of innovation but also with its understanding from a non-orthodox economic perspective.

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65 The technical discussion of the theoretical background of the OECD model is out of the scope of this work, a detailed analysis can be found in Roberto E Lopez-Martinez, op. cit. note 64, ch. 6.

Our analysis suggests that both orthodox and heterodox economic approaches have been present in the genesis and evolution of science and innovation policies and that the influence of the latter has increased over time. It could be argued that there is coexistence and even convergence in the use of these perspectives in policymaking. Nevertheless, we have also shown that the systemic properties of science and innovation policy are independent of the economic models used in their design

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Table 1. Basic policy actions of the OECD system

General Objective	Specific Actions
Coordination of policies across main government departments	Determination of priorities in the government programmes of oriented R&D
Creation of a general environment for innovation	Support for the scientific infrastructure (education and fundamental research)
	Policies to encourage R&D and innovation in the business sector[66]
	Ad-hoc institutions to finance the development of inventions
	R&D loans
	Fiscal policies.
	Government procurement policies
	Encouraging cooperative research
	Improving technical communications and advisory services
	Training policies to improve management and expertise devoted to technical change
	Promotion of university-industry linkages
International cooperation	Standard indicators and information
	Exchange of experiences
	Harmonisation of policies
	International scientific cooperation
	Assisting countries in the process of development

Sources: Christopher Freeman et al., op. cit. note 50, p. 105-111; OECD, Piganiol Report, pp. 167-171; OECD, Brooks Report, pp. 89-108; and OECD, Delapalme Report, pp.93-107.

66 From the 1970s onwards, policies oriented to the business sector include two broad approaches: those of a general nature and specific sectoral policies.