Chapter 4
Innovation Policies: Strategy of Growth in a Complex Perspective

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Abstract The aim of this chapter is to highlight new understandings of innovation as an interactive process in relation to economic growth. The resulting ideas could be of considerable interest to innovation policy makers. Two impacts are of considerable potential importance. The first relates to the absorption of complex and evolutionary systems dynamics ideas into the study of innovation, and growth. The second relates to the synthesis of complex systems ideas with evolutionary models of innovation, and growth. Considering innovation as a complex multi-level process means that it is not possible to devise the context into independent ways and that it is not enough to provide policymakers with simple solutions, but it should help them formulate and address questions that are appropriate to the evolutionary and complex context within which they operate.

Keywords Innovation • Complex systems • Policy making

4.1 Introduction

In the past, many historians and economists[1] emphasised the crucial role of technical institutional change in the theory of economic growth. Schumpeter regarded the process of innovation as central to understand economic growth, highlighting that the innovator rather than the investor or the inventor represented the most sensitive individual figure in the economy.

In the globalisation era, this issue is more important for economic development. At present we are looking for rapid and radical technological change that underlies some of the key economic developments. These include: turbulence and instability in industrial markets, major changes in world shares of output, persistent growth

[1]Adam Smith did recognize the great importance of science and technology, even if List (1841) had strongly criticized him and other classical economists for what he perceived as their neglect of technology and skills, that's they did not consistently give it the prominence which List thought that it merited (Freeman 2002).

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rate differences between economy, dramatic changes in company structures and production organisation, persistent high levels of unemployment, and increasing internationalization and economic integration.

The speeding up of the rate of innovation implying changes in technology, international trade and political deregulation registered an intensification of competition both in sectors already involved in international trade and in formerly protected sectors becoming less sheltered than before.

New agents and organisations confront themselves with new problems; new ways are evolving for relating to others and to important issues; the communities adopt tools and techniques ranging from collaborative visioning and decision-making processes to innovative technologies.

In this context the ability of a country to sustain rapid economic growth in the long run is highly dependent on the ways in which it can deal with evolving environment, and on the effectiveness by which its institutions and policies support the technological transformation and innovativeness. Policy makers have a much more complex task. They have to co-ordinate and calibrate three different policy areas: policies affecting the pressure for change (competition policy, trade policy and the stance of general economic policy); policies affecting the capability to impose and absorb change (innovation policy and human resource development); policies aiming at caring about losers in the game of change (social policies and transfer of income to weak regions).

To perform these tasks, complex system supporting institutions and good economic policies is needed, to foster policy co-ordination among different sectoral policies and across different territorial governments. This requirement has to be met because innovation policy affects the capability to innovate, and it needs to be co-ordinated with policies affecting the transformation pressure and with policies affecting income distribution.

Science and technology policy can no further be thought only in terms of research policy. The current territorial division of policy responsibility is not sustainable in globalisation context. For example, European authorities are in charge of policies imposing a pressure for change, while national and regional authorities are left with the responsibility to promote and cope with change. The policy maker can no longer look to research programmes which aim simply at the development of new scientific and technological principles, and results, but it is increasingly necessary to focus also on the application and use of science and technology by companies and by society as a whole because we are living in globalisation era. In fact because of technology is a vehicle for the diffusion of information and knowledge across borders, technological developments have themselves been stimulated by the globalization of markets. Much more evident is the increasing emphasis on the social and economic relevance and impact of research, and on the factors which shape its impact; in particular in areas as work and employment.

Central questions of policy concern how do firms and governments develop strategies for science, technology and innovation; which are the relationships between public and private in the creation of technology; what is the proper role of the public sector in this area; what are the implications of increasing

internationalisation for national science policies. Economists and engineers, and in particular politicians are devoting increasing attention to understanding why, how and where technological innovations are generated and how and in which way these can affect the growth of a country.

The traditional literature to the innovation looked at the innovation following a linear approach. The development, production and marketing of new technology are assumed to follow a well-defined time sequence which corresponds less and less to the realities of the innovation process (Fisher 2002).

However, over the last twenty years economic theories of innovation have changed deeply, abandoning the traditional linear view of innovation for adopting systemic, or as we said, a complexity and evolutionary approach.[2] This approach emphasizes the central role of feedback between phases of innovation and numerous interactions between science, technology and economy. All these assumptions provide a foundation for systems approach for the analysis of innovation processes. According to this approach, innovations are seen as part of larger process of knowledge production of economic relevance. The approach stresses that firms do not innovate in isolation, but in interaction with other organizations: other firms, R&D institutions, universities and other forms of producer services (Fisher 2002).

Therefore, the innovation is a process that involves, in each moment, many and different actors, their relationships and the economic context in which they act. Under these perspectives (Kline and Rosenberg 1986) innovation should be the result of dynamic interactions among heterogeneous elements. It should be represented by a model in which the various aspects of economic activity are linked together by multiple relationships of causality and feedback and they are all interdependent elements of the process of innovation.

The aim of this chapter is to highlight new understandings of innovation as an interactive process in relation to economic growth. The resulting ideas could be of considerable interest to innovation policy makers. Two impacts are of considerable potential importance. The first relates to the absorption of complex and evolutionary systems dynamics ideas into the study of innovation, and growth. The second relates to the synthesis of complex systems ideas with evolutionary models of innovation, and growth. Considering innovation as a complex multi-level process (Frenken 2016) means that it is not possible to devise the context into independent ways and that it is not enough to provide policymakers with simple solutions, but it should help them formulate and address questions that are appropriate to the evolutionary and complex context within which they operate.

Following these suggestions, the paper analyses the most recent studies framing the innovation in economic growth, according to an evolutionary approach, by highlighting the differences with neoclassical approach. In this respect we offer an innovative approach to the analysis of innovation policies focusing the attention on National Innovation Systems Theory and its further developments. Finally, section six concludes the paper.

[2]This issue was explored in detail in Lane and Maxfield (1997, 2005).

4.2 Innovation Policy

An important topic in the international debate concerns the necessity of an innovation policy. This request derives from important issues outlining the role of technological innovation in modern capitalism development and determining the competitiveness and growth of a country.

In this scenario and in particular in the globalization era, the link among technology, innovation and competitiveness cannot be understood by using the traditional approach that focuses on the individual firms. The diversity study is the key to understand that linkage; the question is no longer how to characterize the similarities between firms, but rather what sense to make of the difference among them (Metcalfe 1994).

The implementation of innovation policy is not simple, despite the widespread attention and efforts dedicated to innovation issues from researchers and policy-makers. It not possible to theorize simple policy prescriptions and devise context-independent ways to sustain it but it is important to conceptualize innovation as a complex, multi-level process. The inventions performed and the theoretical framework are not always perfectly synchronized because they continually evolve; the relationship among these actions involves different processes and institutional levels and they occur on different time. So, it could happen that the actors that are responsible to guide and implement policy are generally different from those that program concrete policy measures.

Furthermore, some goals of innovation policy would need the implementation of coordinated actions involving multiple policy fields and because policy programmes, once established, develop and continue over time, there is the risk that interventions may overlap by hampering the effectiveness of policies (Lane and Maxfield 2005).

From this, it follows the reject of the assumptions of neoclassical economic approach—representative agent, rationality axioms, stable equilibrium—and the understanding of behaviours in evolutionary context outlining the importance of history and the significance of small difference in behaviour. Of course, in this context also the innovation policy has to change perspective. The policy decisions are usually concerned with matter of details (single country, single firm, single agent).

Up to now, in fact, little importance has been attached to the relation between both the actors of economics system and innovation activities and other fields of economic policy. But the economy is a system, so it is necessary to understand it to relate both partial decisions and overall regulation. Briefly it is necessary a systemic approach (Smith 1991).

4.2.1 Neoclassical Approach

The neoclassical approach, based on the existence of competitive equilibrium with well-known assumptions regarding strict convexity, constant returns, complete market, perfect information, absence of externalities and public goods and so on, has dominated the analysis of macroeconomic policy. In fact, policy interventions derive from analysis of the welfare properties of competitive systems (Smith 1991). If those assumptions don't hold, a market failure occurs, implying that it is not possible to achieve an optimal equilibrium, and the public sector may intervene to overcome such failure.

The rationale of traditional analysis of technology policy is based on market failure arguments and social inadequacy of private incentive mechanism, owing to a combination of asymmetric information and moral hazard under uncertainty. The policy measures are seen in terms of adjustments towards competitive equilibria and this consideration is true for macroeconomic and microeconomic analysis.

In these standard models the government is assumed to know the market failures and how to correct them. The purpose of the policy maker is to maximize a social welfare function under the constraint that individual agents maximize their selfish utility function. The social planner is well informed about the economic situation and is able to intervene efficiently implementing incentive schemes, choosing the level of innovative activity to engage in. Then, R&D is one of those activities that cannot be left entirely to the private sector because this will lead to under-investments. To reverse this trend governments put in place a whole host of especially fiscal measures, ranging from governmental grants and contracts to targeted tax incentives, in order to encourage enterprises to commit more resources to R&D (Mani 2001).

Nevertheless, many researches have demonstrated that the neoclassical approach is unsuited to analysis of problems of technological change (Smith 1991).

The fundamental limitation of neoclassical policy framework derives from the underlying concepts of production and competition. The production is a process of combination of factors and not a technical process of transformation input. Considering that producing and techniques are well not the decisions of firms regarding from one side what to produce and from other side how to produce: two decisions are path independent. Competition instead is a process of optimization of above decisions. In this context, the relevant information is not the technological knowledge but the price information. In this way, the economy is represented like a deterministic system in which the fundamental internal processes are those which adapt to exogenous change rather than those which endogenously produce change (Smith 1991).

The research programme is seen as method of generating the optimal level of information and not as search for new methods of techniques producing endogenous change. The market failure and the consequent government intervention, that is an adjustment towards equilibrium, don't concern internal transformations that may change the nature of competitive equilibrium. So, the policy can be a

choice among states characterised by given techniques rather than by processes of search of new states.

4.2.2 Evolutionary Approach

The neoclassical approach starts from the assumption of representative agent, static equilibrium and so on, whereas the evolutionary approach, by using biological metaphors, starts from two assumptions: the consideration of heterogeneous agents or economic units (firms, consumers, or even technologies) disclaiming the standard neoclassical concept of representative agent, and dynamic equilibrium. Evolutionary economics, inspired from Schumpeter's (1912) notion of disequilibrium dynamics resulting from the introduction of innovations, pays particular attention to the role of technology and institutions in the process of economic growth.

Social system is conceptualized "*as compose of different domains e.g. the separated domains of technology, economy and institutions. … Each of domains has its own dynamics and explanatory process, but what is important is that the domains expert strong mutual influence. Thus, the perspective offered by these theories is that of the world economy as a process of constant transformation. Technologies and institutions change over time, and what drives economic growth in one era might become much less important, or might be substituted by a different factor in a different era. In terms of economic growth rates, such a process is quite different from the neo-classical notion of steady-state growth*" (Verspagen 2001, p. 5).

Each system is a set of elements that interact with each other or even in relation to each other; it is also an element of another system. This explains, why when speaking of interaction or interdependence, we also speak of mutual influence of the elements. Any shift or change of a component of an organization (as a system) makes a change of the system itself in its totality (Barile et al. 2012). Under those assumptions,[3] the systems theory observes entities and their environment through a systemic viewpoint, starting with the analysis of fundamental elements and finally considering more complex related systems. Each system is related to other systems, placed at higher level of observation, defined supra-systems, whose traits can be detected in their own subsystems.[4] The analysis concerns a system made up of many parts or structures. In this sense, every entity (a firm, or simply an individual, a consumer, or a community) as a system can be considered a micro-environment, made up of a group of interlinked sub-components which aim towards a common goal.

[3] See also Barile (2000, 2008, 2009), Golinelli (2000, 2005, 2010), Barile et al. (2012).

[4] Principle of system hierarchy.

In this context, the policy based on the repair of a defective co-ordination mechanism (market failure) has not relevance, but policy interventions are related to shaping the potential technological trajectory.

Evolutionary approach concerns endogenous change, evolution and economic development, so that the policy question is that of increasing creativity, technological opportunity and market development.

The policy maker is no more considered as a fully informed economic agent, having a better understanding of market situation and technological knowledge. On the contrary, he has to learn about the different situations and about the policies he has implemented in order to adapt them in case of inefficiency. The objective of a policy is generally not to reach a predetermined result or technological output, but to improve innovation processes, learning abilities and adaptive behaviours of economic actors and interaction between them, to foster the competitive performances of the economic actors and systems.

The policy has then to stimulate the technological and innovative capabilities of organizations, where stimulating innovation means enhancing learning processes of organizations, generating and coordinating variety within the economic system, influencing the various selection mechanisms in order to create new knowledge (Llerena and Matt 1999).

There is a need for policy intervention to improve the performance of the system by coping with the technological evolution. The modes of intervention cover a large range of policies, from education to technology policies, from generic R&D expenditures incentives to public procurements. In the evolutionary context, the scope for policy is not optimise with respect to some objective function but rather to stimulate the introduction and spread of improvements in technology (Nelson and Nelson 2002).

There are some central issues in technology policy as seen from evolutionary perspective. A crucial distinction between policies which take the innovation possibilities of firms as given and those which seek to reduce the cost of research to the firm. R&D subsidies and tax incentives for R&D are typical example or policies to increase the pay-off to innovation either in terms of public procurement of R&D intensive products or through the duration and scope of patent protection. Policies to change the innovation possibilities of firms would include collaborative R&D programme and policies to ink internal efforts of firms with public R&D carried out in the science base.

In an evolutionary framework, policy should be structured around important arguments: operation of economic and social mechanism which generate experiment and search generally; the operation of selection mechanisms at differential levels; the interaction between institutional structures and strategic behaviour. In the evolutionary context, it is the technological performance to become a fundamental object of policy. The aim of innovation policies is to relate to other policy arena, to regulate the differential impacts of other policy actions, to develop and to maintain the ability of firms to operate in technological trajectories.[5] In the last

[5]For a firm the trajectory is determined by large-scale, often global, trends in demand and technological opportunity which are usually uncertain and at best involve risk for the firms.

cases in particular the ability of firms to regain trajectory may depend on policy support.

4.3 The Innovation as Strategy of Economic Growth

It is undisputed that innovative activity has been the most important component of economic growth. Empirical researches[6] bring out that technological change is central in explaining the inter-economy growth rate differences and that inter-industry R&D differences are highly correlated with productivity and growth rate differences. In fact much of public expenditure in R&D is aimed to improve growth performance.

To increase the output of the economy it's possible to choose two ways: by increasing the number of inputs that go into the productive process; by considering new ways to get more output from the same number of inputs by productivity increase. In this fundamental sense innovation drives economic growth. This is one of the most consistent findings in macroeconomics, and it's been true for centuries. Nowadays, policymakers face the economic challenge of competing in a global economy in the midst of a slow recovery from crisis. Solutions could be to increase innovative capacity across the economy so that innovation drives productivity growth and drives economic prosperity and global competitiveness.

4.3.1 The Innovation in Economic Growth Modelling: An Overview

In the 1940s the economist Joseph Schumpeter asserted that "*competition from the new commodity, the new technology, the new source of supply, the new type of organization, competition which commands a decisive cost or quality advantage and which strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives*" (Schumpeter 1942) assigning a central role to innovation as a driver of growth.

Starting from Schumpeter's descriptive analysis, the importance of technical progress was recognized in the neoclassical growth models (Solow 1956) but the determinants of the level of technology were not discussed in detail and the technology was considered as an exogenous factor. Later Solow developed a formal neoclassical model of growth, based on the concepts of production function where output is a function of inputs and reaches long run equilibrium. Economic growth is the result of the accumulation of labour, capital, and other production factors with diminishing returns to scale. The economy converges to steady state equilibrium

[6]See Innovation and Research Strategy for Growth BIS economic paper n.15 dic 2011.

where the level of per capita income is determined by savings and investment, depreciation, and population growth, but where there is no permanent income growth. In the long run, growth in per capita output depends only on the rate of technological progress. The theory offered no account of how this happened: technological improvements emerge from outside the economic system, and they are not the result of decisions within it.

It is not a theory of the rate of economic growth rather a theory of the properties of an aggregate economy growing at an exogenous rate. Essentially this theory had been constructed to explain various stylised facts of the growth process including the constancy over time of the distribution of income and the productivity of capital (Metcalfe et al. 2000).

From the 1980s, growth research has focused on understanding and endogenizing technical progress, by building into the models knowledge-creating investment, to analyse deeply the sources of long-run growth.

This allowed mutual cause-effect relation between growth and innovation. In endogenous innovation models technological progress is the key to long-run growth, inside the economic process, and it depends on investment in innovation, primarily through investment in R&D and human capital. Increasing returns to scale, which follow from the externality aspects of technological change, is the process used to explain economic growth.

Several models analysed a specific research sector of the economy, which produces both specific new inputs, technical and scientific knowledge. In these models, growth depends both from on increases in the productivity of tools and equipment, resulting from technological change, and from "spillovers" of knowledge among different areas. Because production functions are not independent, and the knowledge input can enter into all firm-level production functions, the spillovers generate increasing returns. In this type of growth models, despite neo-classical growth theory, the growth rate can be permanently increased by activities enhancing the use and the flow of collective knowledge in the system (Romer 1990; Aghion 2005; Aghion and Howitt 2009).

Modern growth theory is largely built on models with constant or increasing returns to reproducible factors as a result of the accumulation of knowledge. New or improved technology can be achieved through its own research and innovations, through the absorption and adaptation of foreign technologies, or through a mix of the two ones.

Innovation is conceptualized as a knowledge production activity. "*Similar to any kind of production activity, inputs are transformed into output where inputs are mainly knowledge and research equipment and output are new products and production processes. This linear view on innovation is well suited for econometric analysis once inputs are proxied by R&D expenditures and outputs by patents. Using such a knowledge-production-function, one can measure the return to R&D investments at regional or national levels as well as the extent to which regions/countries benefit from R&D invested by other regions/countries, otherwise known as spillovers*" (Frenken 2016, p. 3).

Under the assumptions of the linear model (Arrow 1962), the economic question holds whether the R&D investments are below the socially optimal level. As seen briefly above in growth modelling, innovation issue has been a continuing problem, so that on the one side there are some growth models putting the main emphasis on accumulation of (tangible) capital through investment and the growth of the labour force and left all other influences to be subsumed in a "residual factor", on other side, the so-called "New Growth" Theory[7] breaks away from this tradition and moves "intangible investment" in education, research and development to the centre of economic growth[8] and development. The evolutionary approach outlines the importance of a new concept: complementarity.[9]

4.3.2 The Evolutionary Approach to Innovation in Economic Growth

Evolutionary theory criticises neoclassical theory for neglecting the question of the determinants of technological progress. In the neoclassical growth model, the contribution of a new technology to economic growth cannot be discussed for two reasons. First, we usually are referring to a one-sector model in which a homogenous product is consumed and invested simultaneously. Second, technological progress is assumed to be exogenous. In contrast to this, evolutionary theory underlines that technological change is a complex, interacting process of invention, innovation and diffusion.

The evolutionary approach suggests that a useful description of economic systems has to incorporate the emergence of new elements of the economic process - technical and social innovations as well as new knowledge. The growth and the process of economic transformation have to be analysed as evolutionary technologies associated with increasingly higher levels of worker productivity, and the ability to produce new or improved goods and services.

This implies, first of all, differences in economic growth (both over time and between countries) which are difficult to predict ex ante, but often have clear

[7]New Growth Theory (NGT) is the view that technological change is essentially an economic phenomenon, or at least explicable in economic terms. Furthermore, the mechanics of economic growth emphasized by NOT captures the traditional idea of uneven growth: some sectors generate more economic growth than others, for example through the creation of new knowledge.

[8]In the 1991 the World Bank in our report has established that "it is intangible investment in knowledge accumulation, which is decisive in the economic growth rather than physical capital investment" (Freeman 2002).

[9]Nelson and others have pointed to the complementarity of all these variables. "The contribution of capital accumulation to growth depends not only on its quantity but on its quality, on the direction of investment, on the skills of entrepreneurs and the labour Force in the exploitation of new investment, on the presence (or absence) of social overhead capital and so forth (Freeman 2002).

underlying explicative factors ex post. There could be historical periods of convergence during times when institutions and technological developments allow this, but periods of divergence of economic growth must also be expected. It means that in the long run, economic growth is not a process of general convergence. Any distinction between cyclical variations and trend growth is problematic.

In the neoclassical approach to economic growth the production is treated as a mechanical rather than an organic process and the social and organisational aspects of production are ignored. Of course this theory is not compatible with the idea of growth as transformation since it excludes from consideration the most pervasive of all the stylised facts of economic growth, structural change.

In order to analyse these issues, some economists left the traditional equilibrium oriented path of neoclassic theory and argued that the evolutionary paradigm is more adequate for analysing development processes in the system, characterized by strong uncertainty and dis-equilibrating forces,[10] and is composed of heterogeneous actors.

Under evolutionary perspective (Verspagen 2001), as asserted by new growth theory, technology is a key factor driving economic growth and the changes in growth rates, but what is specific to this approach is the question of how technological change contributes to the variability of trend growth rates.

To answer this question we have to distinguish between radical and incremental innovation. Radical innovations offer new possibilities for long-run changes in the trend rate of economic growth. Radical innovations break up the existing economic structure and dependencies in the economy. This causes changes in the growth rate that are again difficult to predict in a detailed way ex ante. Incremental innovations are linked with the diffusion of the radical innovations throughout the economy, and they depend on the specific historical and institutional context.

The distinction between innovation and imitation is also important. Technology cannot be fully appropriated by the firm that develops an innovation and quickly technological knowledge flows to other firms and other nations. While innovation may lead to divergence among firms or nations, imitation tends to erode differences in technological competencies, and therefore lead to convergence. For those reasons innovation and diffusion together may lead to turbulent growth paths.

Another important aspect of an evolutionary approach of economic growth regards the growth of new industries and the decline of old ones. The notion of radical and incremental innovation is pivotal in this issue. Radical innovations open up new possibilities for economic activities and often create new industries, or drastically revitalise existing industries. Incremental innovation is then one of the driving forces behind the growth of these industries. It happened because the process of economic growth is characterised by structural change. All these considerations are linked to the notion of economic selection. In evolutionary

[10]In short when economics are out of equilibrium they stay out of equilibrium. But they always exhibit order and that order reflects, and might be measured in terms of processes of interaction and the patterns of co-ordination that ensue.

economics, competition is seen as a process that is important in terms of its dynamics, not its long-run tendency. The dynamics of selection drive economic growth.

4.4 Innovation Policy in the Globalization Scenario

> With the fall of Keynesianism in the 1980s and the rise in global competition in the 1990s, innovation policy has become the cornerstone of economic policy in every high-income country or region (Frenken 2016, p. 2).

An intensification of world trade and stronger competition of national economics on internationally mobile production factors that put new challenges to economic policy are closely associated with globalization.

The globalizations of technology can entail one or all of the following issues:

1. The global exploitation of technologies through patents and licenses;
2. The global sourcing of R&D through alliances and joint ventures with foreign companies or universities;
3. The global production of R&D through overseas subsidiaries.

In the last years, it has attempted to distinguish different meanings of the globalisation of technology measuring each of them quantitatively and providing appropriate policy analysis on each dimension, through three main categories (Archibugi 2000):

1. The international exploitation of nationally-produced technology;
2. The global generation of innovations by multinational enterprises;
3. The global technological collaborations.

The key to achieve long run economic growth and welfare is to increase learning. Although the benefits associated to each knowledge-intensive transaction will not be equally distributed among the participating countries, the relevant aim of public policies should be to involve national economic agents in knowledge exchanges.

Policy-makers should support and reinforce (and if necessary initiate) structural change, investing public resources (or providing incentives for private investment) in the technological capabilities which define the new epoch of growth. In promoting innovation policies in the globalisation they have to follow two approaches:

1. The first stresses the importance of spatially bounded (local, regional or national) innovation systems, paying less attention to the differences among neighbouring firms operating in different industries;
2. The second approach stresses instead the role of global factors in innovation systems overlooking location-specific aspects of this process.

Policy makers have to try to identify the relative role of regional, national, sectoral and global factors in shaping innovation systems. The innovation systems

concept is itself flexible enough to allow us to take into account the relative importance of each of these factors.

4.4.1 National Innovation Systems

For a long time, innovation has been analysed by a linear model. The development, production and marketing of new technology were assumed to follow a well-defined time sequence which doesn't correspond to the real facts of the innovation process. The criticism has led to a broader view of the process of innovation as an interactive process. This approach emphasizes the central role of feedback between phases of innovation and numerous interactions among science, technology and economy. All these assumptions are the foundation of systemic approach for the analysis of innovation processes. According to this approach innovations are seen as part of larger process of knowledge production of economic relevance. The approach stresses that firms do not innovate in isolation, but in interaction with other organizations, other firms, R&D institutions, universities and other forms of producer services (Fisher 2002).

The work in institutional economies has emphasised that knowledge storing and learning activities are heavily dependent on the institutional context. This leads to a broad analysis of the combined technical and institutional learning processes in the dynamics of knowledge.

Analysis of technology performance and policies has traditionally focused on inputs and outputs, the measurement of which is standardized across OECD countries. The limitations of this approach have become evident over time because these indicators, important sources of information about the content and direction of technological endeavour, do not offer convincing explanations of relation between innovation and growth. They do not consider the interactions among various actors in innovation process. Evolutionary theory highlights the role of those interactions among the people and institutions involved in technology development.

According to the systemic and evolutionary perspective the analysing innovative activity is equivalent to consider it as a structure formed by economic, technological and social elements, in relation to each other, and by interacting influence the creation of innovation processes. The innovation is observed as a complex phenomenon, emerging from synergistic interactions between multiple actors and the final resultant is greater than the sum of the actions performed by every single part.

National Innovation System (NIS)[11] is a concept based on the assumption that understanding the linkages among actors involved in innovation process is the way

[11]"The origins of the systems concept, applied to innovation, lie in the concept of national systems of innovation (Freeman 1987; Nelson 1988; Ludvall 1992). The concept emerged as an alternative way to explain the innovation process, improving on an earlier view that considered this process as a simple linear progression of scientific research" (Iizuka 2013, p. 2).

to increase technology performance. It follows systemic and evolutionary approaches to the study of technology development as opposed answer to the "linear model of innovation".[12]

The innovation system is therefore composed of many relevant factors as institutions, political processes, public research facilities (universities, research institutes, public sources subsidies, incentives, etc.), financial institutions, and so on. In this view the dynamics of innovation are explored in their different phases in order to investigate how they influence and are influenced by the social, institutional and economic context composing the structure of the NIS. The point of view adopted in the analysis of a national innovation system is innovative firm as the main responsible of innovative activity. The main organizations with which innovative company interacts are subsystems of the national innovation system. In particular, these other companies (competitors or suppliers) are universities and other scientific research centres, financial institutions and the government (Barile et al. 2012).

The innovative performance of a country depends mainly on how these actors interact to each other as elements of a complex system of knowledge creation and on technologies they use. How technological change and potential growth are effectively reached is the result of how agents can exploit their interactions, their environment and can learn from the past experiences. Therefore in the definition and implementation of innovation policies a strategic role is played by National Systems of Innovation as a set of organizations, institutions, and linkages for the generation diffusion, and application of scientific and technological knowledge operating in a specific country. In the past, the concept of national system had a well-defined meaning when basic decisions concerning the science, technology, and innovation policies of a given country were taken essentially at a national level.

Economic globalization has established a new, hierarchical system which can override actions at the community level. Market integration and instantaneous global communication create the potential for huge economic and social impacts. In the globalisation where the international linkages are dominant the NSIs are becoming more open systems. Moreover, the national borderline is now less meaningful because national power is flowing partly upwards towards supranational institutions and partly downwards towards regional and local institutions.

The evaluation of national innovation systems regards four types of knowledge or information flows: interactions among enterprises; interactions among enterprises, universities and public research institutes; diffusion of knowledge and technology to enterprises; personnel mobility. It can also be analysed at sub-regional,

[12]"Innovation is thus the result of a complex interaction between various actors and institutions. Technical change does not occur in a perfectly linear sequence, but through feedback loops within this system. In the centre of this system are the firms, the way they organise production and innovation and the channels by which they gain access to external sources of knowledge. These sources might be other firms, public and private research institutes, universities or transfer institutions—regional, national or international. Here, the innovative firm is seen as operating within a complex network of co-operating and competing firms and other institutions, building on a range of joint ventures and close linkages with suppliers and customers" (OECD 1997, p. 12).

national, and international levels. Collaborations and international technology flows have growing importance, but national level seems the most significant for the role of country specific interactions in building an innovation climate.

4.4.2 Further Developments of Systemic and Evolutionary Approach to Innovation

Under the same assumptions of National Innovation Systems theory, it has been formulated the "Triple Helix Model" (Etzkowitz and Leydersdoff 2000).

The model is a metaphor which highlights as the power of the innovative capacity of a country system or of an innovative local system depends on the synergistic interactions among the three main institutions (or "helix"):

1. The state (national and local public institutions);
2. The research system (universities and research organizations);
3. The production system (companies with high technological intensity).

This model tries to capture the reciprocal interactions between the actors on the corporate knowledge process. In the Triple Helix model the university plays a key role bringing its action at the level of other spheres and adding to the exclusive role as producer of knowledge and the subject directly active in promoting innovation. Finally, the State and, more generally, government institutions take on a new and more modern function. In the Triple Helix model, government institutions, whether central or regional and local, not only perform the task of supporting financially the research activities of other entities by public funds.

The action of the three subjects is observed as a sort of "Triple Helix" in which the interactive relationships among the spheres are constantly created. The spheres act in complementary and continuous actions, almost playing each other's role, not losing the sight of their mission.

In this way, the state is committed to defining new rules that favour a free search of high quality, which promote a permanent and stable co-operation between universities and enterprises. This encourages qualified research personnel training, which favour the mobility of researchers between the public and the private sectors, the valorisation of research results, the creation of new businesses from university research activities and the spread of the venture capital business.

The state becomes the subject who writes the rules and ensures the respect by systemic relationships between businesses and universities. The goal is to realize the best framework and system conditions to promote the growth of the innovation capability of the country.

The systems approach, as argued (Barile et al. 2012), is one of the most important recent revolutions for the study of complex phenomena such as the innovative activity. However, none of the theories set forth above is limitless. The Theory of National Innovation Systems, while highlighting the systemic nature of innovative

activity becomes less and less sustainable in the current context characterized by increasing levels of globalization and dematerialization that reduce the time-space boundaries. The Triple Helix model has the merit of raising the role of universities in economic entity which, turning research into business ventures is able to transfer knowledge to the market and contribute to the development of the system. However, some academics have indeed expressed some concerns. They fear that the main missions of the universities (teaching and research) may be penalized. However, it was observed that a greater integration between the academic world and the business world is without prejudice to research and training and contributes to increase the transfer flow of knowledge to science and technology, to stimulate the creation of new jobs and new forms of work and to increase the areas and forms of funding of university research.

Acting on the research capabilities or on the social and human capital reinforces the new knowledge creators, acting on the absorption capacity or the technological and innovative performance, strengthens the diffusion and transfer of technology. For this process, are important not only human resources, but also the stock of human capital and the development of new skills and knowledge that can ensure the constant cultural and professional development (Barile et al. 2012).

4.5 Policy Implications

The theoretical assumptions of NIS are the evolutionary view of technological innovation and economic growth.[13] The concept emerges with the aim to increase policy capacity for national economic growth, in response to the challenges raised from new technologies and international competition. The NIS approach is developed for policy innovation that consider change, complexity and systemic approach. Specific models are characterized by interactions between institutions and technology within individual systems, in which elementary actors create change and adapt to change to mitigate tension and disorder that arise from change.

From evolutionary perspective the policy maker has to consider a considerable deal of indeterminacy and uncertainty. Traditionally a policy maker for reaching equilibrium is obliged to correct the system deterministically with his maximizing calculation. In the NIS approach a policy maker is a part of the systems and due to evolution he must adjust the policy over time. This mechanism of adaptive policy is in contrast to conventional thought. Also the role played by a policy maker is seen differently from conventions as he stands in close interactions with the systems which he coordinate. A policy maker must be adaptive, adjusting a policy with the operation of the system to which the policy is aimed to introduce an innovation".

For all those reasons, a national innovation system offers new insights for government technology policies.

[13]For a deep overview see Shulin (1999).

> Most government intervention in the technology area has been the aim to correcting market failure. In the interest of maximising returns to the general public, technology policies have focused on stimulating or supporting R&D spending by industry through instruments such as R&D tax credits and subsidies. The concept of national innovation systems directs the attention of policy makers to possible systemic failures which may impede the innovative performance of industry. The lack of interaction between the actors in the system, mismatches between basic research in the public sector and more applied research in industry, malfunctioning of technology transfer institutions, and information and absorptive deficiencies on the part of enterprises may all contribute to poor innovative performance in a country (OECD 1997, p. 41).

NIS studies (OECD 1997; Shulin 1999) consider the need of new types of policies to overcome systemic failures, and in particular policies addressed to networking. Networking schemes improve the interaction of actors and the role of institutions within national innovation systems. Such policies put the emphasis on the role of joint research activities and other technical collaboration among enterprises and with public sector institutions; policies aimed to promote research and advanced technology partnerships with government are important in this context.

It has been distinguished (Metcalfe 1995) also technological policies of political parties, especially of the government, into two categories:

- Policies to create infrastructures that promote innovative activities both regulative that physical, as buildings, transport, telecommunications, science and technology parks (Barile et al. 2012);
- Policies to develop a specific technology through an indirect intervention (subsidies to private enterprises to encourage them to work on that specific technology) or through direct government intervention (creation of public laboratories that work on that specific technology or in research and development).

Technology policies and infrastructures are implemented by informal flows of knowledge and access to technical networks. They see the value of encouraging the development of innovative relations among firms, and thus establish appropriate competition policy frameworks.

Another policy priority is to increase the innovative capability of firms. From the innovation systems perspective, this means to make enterprises able to access the appropriate networks, to find and identify relevant technologies and information, and to adapt such knowledge to their own needs. It may translate in more investment in internal R&D and information technology. Innovation policies should not only regard the capabilities of individual firms but also the networking and innovative performance of firms and sectors that driven economic growth.

4.6 Conclusions

In the globalisation era innovation issue has becoming a much more important question to economic development. At present, we are looking for rapid and radical technological change that underlies some of the key economic developments.

Technological change provides a privileged viewpoint from which to understand the dynamics of globalisation. New technologies have always been international scope; the transmission of knowledge has never respected states' borders.

There is a complex interplay between technological change and globalisation. On the one hand, new technologies act as a powerful vehicle for the diffusion of information across distant communities. For example, it would be difficult to imagine the current globalisation of financial market without the existence of the new information and communication technologies, since they have made it possible to obtain instant transactions across the world. On the other hand, the process of generating and discussing new technologies has been moulded and strengthened by the flows of individuals, commodities and capital.

Globalization represents a change in human system complexity. To deal with it, it is necessary to assure variety of responses and f1exibility. We need a creative approach on all the components of the action process: from organization, to problem definition, to solution design. To perform these tasks, complex systems are required to support institutions and good economic policies, in particular a policy co-ordination both between different sector policies and across different territorial governments. This requirement has to be met because innovation policy affects the capability to innovate so it needs to be co-ordinated with policies affecting the transformation pressure and with policies affecting income distribution.

The ability of government in this scenario is to adapt the policies to the different situations.

The adoption of a complexity and evolutionary perspectives to innovation can help policymakers to realize policies able to promote innovation processes. Policymakers need new tools to understand the implications of their policies at all different involved levels. Policy interventions directly influence and determine interactions and changes within sectors, firms or territories. They have a deep impact on macro variables such as imports and exports, investment, overall expenditure both in public and private R&D.

In other words in a systemic/evolutionary approach innovation policies should be evaluated with respect to the systemic effects they produce.

This implies that policies should be monitored and evaluated in new way, by devising new indicators, new procedures that consider either the various needs that different innovation processes require in order to produce tangible results in term of economic growth, either the processes of interaction among the involved actors.

For example, while countries can stimulate investments in R&D in private sector by merely fine tuning financial instruments, such as research grants and tax incentives in the case of developing countries a mere fine tuning of the financial instruments while necessary are not sufficient. An important element or technology policy has to be the development co-operative strategies aimed at collective provision of scientific research. In other words, policy might well be proactive—and should often be. In other words, a 'problem' might be something that has not yet emerged.

Central questions of policy concern how do firms and governments develop strategies for science, technology and innovation; which are the inter-relations between public and private in the creation of technology; which is the proper role of the public sector in this area; which are the implications of increasing internationalisation for national science policies.

The policy maker can no longer look to research programmes which aim simply at the development of new scientific and technological principles and results, but it is increasingly necessary to focus also on the application and use of science and technology, by companies and by society as a whole because we are living in globalisation era.

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