Rationales for public policy intervention in the innovation process: A systems of innovation approach

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1. INTRODUCTION

The question why the government should intervene to support *R&D and innovation* although a recent one, can be traced several decades back (Arrow, 1962, Nelson, 1959). Despite the extensive literature on innovation, the rationales for public intervention in innovation are still subject to an intense debate, especially related to new theoretical perspectives such as the system of innovation (SI) approach.

Innovation policy can be defined as "the public actions that influence innovation processes, i.e. the development and diffusion of (product and process)[1] innovations". The objectives of innovation policy are often economic ones, such as economic growth, productivity growth or

[1] By product innovation we refer to both goods and services; by process innovation we understand both productive and organizational innovations (Edquist, 2005).

increased employment and competitiveness. However, they may also be of a non-economic kind, such as cultural, social, environmental, or military. As in any policy, the objectives of innovation policies are determined in a political process and not by researchers.

Innovation policy design is a question of the division of labour between, on the one hand, the actions of private firms and, on the other, the actions of public organisations - with regard to factors influencing innovation processes. For example, large-scale and radical technological shifts rarely take place without public intervention, while incremental innovation is normally carried out by firms without any explicit support from the government. To discuss the division of labour between private and public actors in innovation is the same as discussing the *rationales*, *reasons* or *criteria* for public policy intervention. That is, when, how and why should government intervene in the economy supporting certain innovative activities.

Innovation policy is partly influenced by the dialogue between policy and theory. The discussion on the rationales is inherently linked to the theoretical approach that one chooses to explain innovation and technological change. New theoretical insights provide the grounds for new actions whilst old actions are abolished. In this chapter the central questions in how this link between theory, policy and practice changes by the emergence of the innovation system (IS) approach.

Researchers in economics of innovation have, for some time, distinguished between rationales for intervention under the neoclassical and the evolutionary theory (Bach and Matts, 2005: Lipsey and Carlaw 1998; Smith 2000)). The rationale for public intervention under the systems of innovation perspective has recently received attention among scholars and practitioners (Koch, 2003; OECD, 2001; Smits and Kuhlmann, 2004; Woolthuis et al 2005). However, there has not been yet an attempt to profoundly discuss the implications of the adoption of the SI approach for the design and implementation of innovation policies. We will try to pursue such a discussion both from a theoretical perspective and a practical one, including some examples of innovation system based policies.

Since the emergence of the system of innovation concept in the 1990's in academic arenas (Freeman, 1987; Lundvall,1992, Nelson, 1993 and Edquist 1997) the concept seemed rapidly to attract the interest of policy makers, especially international policy think-tanks such as the OECD (Mytelka and Smith, 2002)[2]. Its many initiatives on systems of innovation and policy (OECD, 1995a, 1995b, 1996, 1999, 2001 and 2002) had a strong impact on the way that national governments started to design

[2] As many studies have argued, the OECD played a significant role in the dissemination of the concept to national governments (Mylteka and Smith, 2002; Godin, 2004; Sharif, 2006)

and implement innovation policies. Today, countries like Finland, Sweden, the Netherlands and Japan have explicitly adopted the system of innovation approach in their innovation policies.

Despite the widespread use of the SI approach in policy-making circles, it remains a fuzzy concept - very difficult to use in practice (Chaminade and Edquist 2006) Therefore much discussion is needed on the implications of the adoption of the SI approach for public policy (*what* to do, *when* and *how* to do it). This paper attempts to contribute to fill this gap by discussing the rationales of innovation policies when the SI approach is adopted.

The paper will be structured as follows. In section 2, we will compare the basic assumptions of the neoclassical and evolutionary-systemic theories and the implications of the adoption of one or another for the rationales for public intervention (why to intervene). We will then introduce, in section 3, some additional issues of relevance for intervention and some principles that emerge when the system of innovation approach is adopted for innovation policy. Finally, in section 4, we will conclude with some open questions and issues for further research.

2. MAINSTREAM ECONOMICS VS. THE SI APPROACH: CONCEPTUAL FRAMEWORK AND RATIONALES FOR PUBLIC INTERVENTION[3]

2.1. The concept of knowledge and innovation in mainstream economics

Innovation policy are the public actions that influence innovation processes. Innovation policy is the result of the interplay between private and public actors but also of the interaction between the innovation scholar community and the policy makers. The way that innovation policy has been designed in a given moment in time partly reflects how innovation was conceptualized at that moment in time, that is, what was the theoretical paradigm used to understand what was happening in practice. There are two largely influential theoretical approaches to innovation: the

[3] In order to simplify this chapter, two main frameworks will be contrasted to each other: on the one hand the neoclassical theory (more specifically the late work in mainstream economics that dealt with R&D and growth), including the most recent additions of the new growth theory and, on the other hand, the evolutionary theory and the related systems of innovation approach. We use the terms neoclassical theory and mainstream economics interchangeably..

neoclassical theory (and later the new growth theories) and the evolutionary/systems of innovation approach.

For the neoclassical scholars, the innovation process was initially narrowed down to research (and invention). For the neoclassical theorists, the process of innovation is often seen as a fixed sequence of phases, where research efforts will turn almost automatically into new products. How to transform the results of the research activity into products or processes that can be used in the economy was considered to be a black box (Rosenberg 1982, 1994). Innovation is thus about the generation of knowledge and knowledge is the same as information, i.e., it is codified, generic, and it is accessible and easily adaptable to the firm's specific conditions.

These tacit assumptions about the properties of knowledge are reflected in the discussion about the process of invention. For Nelson (Nelson 1959) and Arrow (Arrow 1962) the knowledge emanating from research has some specific properties: uncertainty, inappropriability and indivisibility (Lipsey and Carlaw, 1998).

- *Uncertainty* refers to the impossibility to fully know the outcomes of the research process and the risk associated to it [4].

- *Inappropriability*, means that firms cannot fully appropriate the benefits which derive from their inventions. There will always be externalities emanating from the research process. This means that the incentive for research activity by firms is smaller than it would be if it was possible for firms to appropriate all the benefits.

- *Indivisibility* implies that there is a minimum investment in knowledge before any new knowledge can be created.

According to mainstream economics,, the three characteristics of scientific knowledge (uncertainty, inappropriability and indivisibility) will lead to an under-investment in R&D by private actors than what would be desirable from an economic and societal point of view. Policy makers have to intervene because of a *market failure*: economies will systematically under-invest in R&D not reaching the optimal allocation of resources for invention[5]. This constitutes the main rationale for public intervention in research activities.

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[4] The problems of uncertainty in the design of innovation policy will be discussed in more detail in section 3.2.

[5] Indeed research conducted for the OECD countries (Mohnen, 1966 cf Norgren and Hauckes, 1999) has shown that the social rate of return of investments in R&D and Human

The optimal allocation of resources is linked to the central concept of equilibrium in mainstream economics. Markets will always tend to achieve equilibrium under the conditions of perfect information, perfect competition and profit maximization. Economic agents can maximize their profits because they have perfect information about the different options available to them. When this fails to be the case, governments should intervene to mitigate non-desired externalities and asymmetries in information, correct inefficient market structures or eliminate the barriers to entry.

The neoclassical analysis provided governments with strong arguments to invest heavily in fields such as energy, large-scale science and technology projects, defence research, etc. where the public rate of return was expected to be high, the barriers to entry were significant and the externalities were also assumed to be sizeable.

2.2. Rationales for public intervention in the neoclassical theory: market failures

The policy implications that emerge from the market failure theory are actually not very helpful for policy-makers from a practical and specific point of view. They are too blunt to provide much guidance. They do not indicate how large the subsidies or other interventions should be (as it is not possible to determine the optimum level of investment in R&D or innovation activities) or within which specific area one should intervene. Standard economic theory is not of much help when it comes to formulating and implementing specific R&D policies. It only provides general policy guidance; e.g., that basic research should sometimes be subsidised (Edquist 1994; Edquist, Malerba et al. 2004). As mainstream theorists tend to ignore the economic structure or institutional frameworks in which the innovation activity takes place, their policies apply across the whole economy (Lipsey and Carlaw, 1998, OECD, 1998). The market failure approach is simply too abstract to be able to guide the design of specific innovation policies.

Furthermore, as Bach and Matts (2005) acknowledge, when policy makers intervene to mitigate or solve some market failures, they might end up generating more failures. For example, by introducing IPRs to solve the problems of appropriability and incentives, policy makers introduce barriers to the perfect flow of information, thus generating a second market failure. [6]

Capital largely exceeds the private rate of return, therefore providing strong arguments for public intervention in the supply of R&D and the provision of human capital.

[6] This can be mitigated by awarding the patents for a limited period of time.

The neoclassical theory has been expanded significantly over the last two decades, solving some of the problems that the initial theory had in terms of its narrow conceptualization of innovation processes[7]. It can be said that the neoclassical theory has expanded in at least two directions relevant for the discussion on innovation policy (Bach and Matts, 2005): the new economics of science and technology and the new growth theory. The new economics of science and technology sponsored by Dasgupta and Stoneman among others (Dasgupta, 1987; Stoneman and Dasgupta, 1987) has focused on the public good properties of technology, concluding that the justification for the state intervention is stronger for science than for technology.

On the other hand, the new growth theory (Romer, 1986, 1990; Grossman and Helpman, 1991, Aghion and Howitt, 1992) takes seriously a number of issues contemplated by the evolutionary theory which were neglected by the neoclassicals. Among others, the admission of a certain degree of randomness in R&D activities (i.e there is no perfect information on the outcomes of the R&D process), the focus on the importance for growth of technology flows between agents and the acknowledgement that innovation policy is important for growth Verspagen (2005).

Despite the significant progress made by the new growth theory from the initial neoclassical premises, it continues to have great limitations (Bach and Mats, 2005). The new growth theory assumes low uncertainty, while in reality innovation involves a great deal of uncertainty and risk. It is also based on a very simplistic (and linear) relationship between R&D and growth (Verspagen, 2005). And, more fundamentally, it continues to assume that the system can achieve equilibrium. In this sense, alternative theories or theoretical approaches might provide more convincing explanations of innovation that set better grounds for innovation policy.

2.3. The concept of knowledge and innovation in the systems of innovation approach

The SI approach has its roots in a compound of theoretical approaches such as the evolutionary theory (Nelson and Winter 1982). But it was also influenced by institutional approaches (North, 1990) and sociology (Granovetter, 1985) . It emerged as a reaction to the perceived inadequacy of the neoclassical theory to explain innovation processes (Lundvall, 1992) and, as such, most of its building blocks emerged in opposition to

[7] The neoclassical theory has been criticized for considering innovation as a linear process which starts with the investment in R&D activities and the strong emphasis on equilibrium and perfect information.

the neoclassical theory (i.e. highlighting limitations of neoclassical theory and providing an alternative).

The SI approach emphasises the fact that firms do not innovate in isolation but with continuous interactions with other organisations in the system (at regional, sectoral, national and supranational level) (Edquist, 1997, 2005, Lundvall, 1992). The (SI) approach shifts the focus away from actions at the level of individual and isolated units within the economy (firms, consumers) towards that of the collective actions underpinning innovation. It addresses the overall system that creates and distributes knowledge, rather than its individual components, and innovations are seen as outcomes of evolutionary processes within these systems.

The notion of knowledge is also extended from the neoclassical "information" to embrace also other forms of knowledge, such as tacit knowledge. Knowledge can be both general and specific and is always costly to create and diffuse. Knowledge can be specific to the firm or to the industry (Smith, 2000). While in the neoclassical approach information asymmetries are considered to be a market failure, under the evolutionary theory and the SI approach asymmetric information is essential to provide novelty and variety. In this sense, the SI approach links clearly with the evolutionary theory putting the emphasis on the mechanisms of diversity creation and selection (e.g. competition) as the engines of innovation. It also stresses the path-dependency of innovation processes. The SI approach, takes the evolutionary theory as one of the points of departure, to focus on the interactive mechanisms that shape the emergence and diffusion of innovations.

The table below summarises some of the issues related to innovation related mainstream economics and systems of innovation approaches and the policy implications of these approaches. It offers a very simplistic yet easy to understand summary of the main differences between neoclassical theory on the one hand and the evolutionary theory on the other. For the sake of simplification and clarity, we leave aside in this summary the contributions made by the new growth theory and the new economics of science and technology that, as argued before, have kept most of the neoclassical premises intact (Nelson, 2004 cf Sharif, 2006). As Verspagen summarises:

> "The evolutionary tradition and the neoclassical tradition have converged somewhat in the phenomena deemed central within each analytical approach. But they disagree on the essential nature of the growth process. The neoclassical theory conceptualises growth as a deterministic process in which causality is clear-cut and policies can be built on an understanding of time invariant

> determinants of growth patterns. In the evolutionary view, on the other hand, contingencies and specific historical circumstances play a larger role, and casual mechanisms that prevail in one period may be subject to endogenous change in the text" (Verspagen, 2005: 505).

Furthermore, we include the systems of innovation approach under the same heading of the evolutionary theory. This does not mean that we neglect that SI had a great influence from other theoretical approaches such as institutional economics but we particularly focus on those characteristics of the SI approach that draw mainly from evolutionary theory and thus, offer alternative explanations to the neoclassical theory.

Table 1: Two different theoretical frameworks underlying science and innovation policy

	Mainstream	**Evolutionary theory and Systems of Innovation approach**
Underlying assumptions	Equilibrium Perfect information	Non-equilibrium. Asymmetric information
Focus	Allocation of resources for invention Individuals	Interactions in innovation processes Networks and Framework conditions
Main policy	Science policy (research)	Innovation policy
Main rationale	Market failure	Systemic problems
Government intervenes to (examples)	Provide public goods Mitigate externalities Reduce barriers to entry Eliminate inefficient market structures	Solve problems in the system or to facilitate the creation of new systems. Induce changes in the supporting structure for innovation: support the creation and development of institutions and organizations & support networking Facilitate transition and avoid lock-in
Main strengths of policies designed under each paradigm	Clarity and simplicity Analysis based on long time series of science-based indicators	Context specific Involvement of all policies related to innovation Holistic conception of the innovation process
Main weaknesses of innovation policies designed under each paradigm	Linear model of innovation Framework conditions are not explicitly considered in the model (e.g. institutional framework)	Difficult to implement in practice Lack of indicators for the analysis of the SI and evaluation of SI policies

2.4. Rationales for public intervention in the SI approach: systemic problems

Understanding innovation as a complex interactive process has important implications for the design and implementation of any kind of policy to support innovation. It affects the focus of the policy, the instruments and the rationale for public policy, among other issues (Chaminade and Edquist, 2006). The system of innovation approach does not imply that these systems are or can be consciously designed or planned. On the contrary, just as innovation processes are evolutionary, SIs evolve over time in a largely unplanned manner. Even if we knew all the determinants of innovations processes in detail (which we certainly do not, and will never do), we would not be able to control them and design or 'build' SIs on the basis of this knowledge. Centralized control over SIs is impossible and innovation policy can only influence the spontaneous development of SIs to a limited extent.

A main focus of the SI approach is therefore the complex interactions that take place among the different organisations ('actors') and institutions ('rules of the game') in the systems. The SI approach indicates that policy makers should intervene in those areas where the system is not operating well, that is, when there are **systemic problems**. Hence, one condition for public policy intervention is that such systemic problems exist, i.e. problems that are not automatically solved by private actors.[8] Systemic problems can be identified by conducting empirical analyses that explicitly compares systems of innovation.

Innovation policy – or other kinds of public intervention – should be a complement to the market, not replace or duplicate it. If there is no "additionality", the public actions are a *substitute* for the actions of firms.and other private organisations The two are overlapping or competing. It is of great importance that there actually is additionality associated with the public intervention[9]. If not the public resources invested will not influence innovation processes, but lead to increased profits for the firms or to increased spending on other things than those targeted by the policy.

In the SI approach the notion of optimality is considered to be irrelevant. "Market failure" in mainstream economic theory implies a comparison between conditions in the real world and an ideal or optimal

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[8] A second condition that has to be fulfilled for public intervention to be pursued is that the public actors have to have, or be able to acquire, the *ability* to solve of mitigate the problems (Edquist 2001, Chaminade and Edquist, 2006).

[9] Bach and Matts (2005) distinguish between 4 types of additionally: outputs, inputs, behavioral and cognitive and indicate that the question to be asked is whether the policy action is changing the outputs, the inputs, the behavior of firms or the cognitive capacity of the different agents.

economic system. However, innovation processes are path dependent over time and it is not clear which path will be taken. They have evolutionary characteristics. The system never achieves equilibrium. We cannot specify an ideal or optimal system of innovation. Hence, comparisons between an existing system and an ideal or optimal system are not possible. Thereby the notion of "failure" looses its meaning and applicability. To eliminate completely associations to the notion of optimality, we prefer to talk about systemic *problems* instead of systemic *failures* (Chaminade and Edquist, 2006; Edquist and Chaminade, 2006) Some of these systemic problems mentioned in the literature include the following (Carlsson and Jacobsson, 1997, Norgren and Haucknes, 1999: Smith 2000; Woolthuis, Lankhuizen et al. 2005):

- *Infrastructure provision and investment problems*, including the physical infrastructure (transport, etc), the scientific infrastructure (high-quality universities and research labs, technical institutes, etc) and the network infrastructure (IT, telecom). Policies aiming at solving infrastructure provision problems could focus, as VINNOVA shows, on building competence centres[10] as well as creating new ones and investing in business incubators and a seed capital programme for new companies. It can also involve the creation of a large infrastructure to support innovation in a group of SMEs such as investing in a modern greenery facility for flower production.
- *Transition problems*: They refer to the difficulties that might arise when firms and other actors encounter technological problems or face changes in the prevailing technological paradigms that exceed their current capabilities. Firms might not be capable to foresee the emergence of new paradigms, radically new pervasive technologies or significant changes in the markets that require new technological solutions. As we will argue later, the transition from one prevailing paradigm to the next involves a high degree of uncertainty which might prevent private actors from entering the new technological field or market. Technology foresight exercises might help policy makers to anticipate and prevent potential lock-in and transition problems.
- *Lock-in problems*, derived from the socio-technological inertia, which might hamper the emergence and dissemination of more efficient technologies[11]. Firms and other organizations might be locked into existing technologies (and technology systems). The strength of technology systems might hamper the development of new

[10] Competence centres are the result of the interaction between universities and companies in the field of problem-oriented research of high scientific quality (VINNOVA, 2002).

[11] One clear example of lock-in is the fossil energy. The productive system is so dependent on the fossil energy that it is preventing the expansion of new forms of energy (such as solar, aeolic, etc).

technologies alien to the prevailing technological system or technology regime. Lock-in problems might lead to transition problems to the extent that the excessive focus on existing technologies might prevent the firms to foresee the emergence of new technological opportunities.

- *Hard and soft institutional problems*: linked to formal rules (regulations, laws) as well as more informal and tacit ones (social and political culture for instance). The system of innovation approach pays special attention to the role of institutions in the systems. Institutions are *sets of common habits, norms, routines, established practices, rules or laws that regulate the relations and interactions between individuals, groups and organizations* (Edquist and Johnson 1997: 46). The institutional framework plays a very significant role in the production of innovations as well as in the adoption and dissemination of innovations. The government can play a significant role in the development of the formal rules whilst in most cases this role is marginal when the most tacit elements are to be influenced (culture, firm routines, social networks, etc). Policies targeting, for example, the IPR system in a country might contribute to solve some institutional problems (ex. Inadequacy of the IPR system to encourage innovation). Business support services for SMEs might also help to overcome some soft institutional barriers to innovation.
- *Network problems*: which include those derived from too weak linkages or too strong linkages (blindness to what happens outside the network) in the system of innovation. Although it is easy to understand that the system might suffer from network problems that may require some kind of government response, in practice it is very difficult to assess the adequate degree of strength of the linkages in the system. Both strong and weak linkages are reported to have advantages and disadvantages, in terms of openness and intensity of exchange (Nooteboom, 2004). In this sense, policy makers might induce cooperation between the agents. For example, VINNOVA trains innovation system developers, that is, facilitators that can "mobilise the level of commitment and resources needed to create efficient groups and processes which will produce concrete results" (VINNOVA, 2001:11)
- *Capability and learning problems*: these systemic problems refer to the insufficient competences of firms (human, organizational, technological and so forth) which might limit their capacity to learn, adopt or produce new technologies over time. In other words, the system might have the right infrastructure and institutional framework, but the organizations in the system might have difficulties in accessing or creating new knowledge or in transforming knowledge into innovations. Policy makers might support the acquisition of

qualified human resources or the adoption of specific managerial techniques by targeted groups of firms (for examples SMEs).

- *Unbalanced exploration-exploitation mechanisms*: The system might be capable of generating diversity but not having the mechanisms to be able to make the adequate selections or it may have very refined selection procedures but no capability to generate diversity. Policy makers might support the emergence of spin-off companies, for example.
- *Complementarity problems*: the competences of the system might not complement each other or they might not be connected so the positive effects that might emerge from the combination of complementary capabilities are not fully exploited.

Policy makers should thus consider intervening when there is a systemic problem. However, this is not so easy in practice as we have argued before (Chaminade and Edquist, 2006, Edquist and Chaminade, 2006) since the SI approach still has important limitations (Edquist, 2005). We still know very little about how the systems operates in practice, that is, which the activities or functions of a system of innovation are (Chaminade and Edquist, 2006). Furthermore, the SI approach has been criticized for being static, for the lack of attention to policy consequences and for weak links between the micro and system level. From a policy perspective, the discussion on SI based policies has not dealt profoundly with the problems of uncertainty, selectivity and path dependency. While this chapter will be focusing on the later issues, the chapters of Jacobsson, Smith and Hekkert; Teubal, Smits & Kuhlmann and Jacobsson & Carlsson in this book will deal with the issues of the dynamic character of innovation, the policy consequences and the links between the micro and the macro level.

3. UNSOLVED QUESTIONS: ADDITIONAL ISSUES FOR CONSIDERATION UNDER THE SYSTEM OF INNOVATION PERSPECTIVE

3.1. Policy mistakes (and policy learning)

The role of the policy maker under the neoclassical theory was to help the market reach equilibrium (again). In the words of Norgren and Hauknes (1999) we could talk about the optimising policy maker. However, the role of the policy maker under the SI perspective is one of adaptation. Policy makers need to adapt their policies to the identified systemic problems in systems of innovation – and these may change over time. We move from the optimising policy maker to the adaptive policy maker. This means the acceptance of mistakes in policy making but also points to the importance of evaluation of policies and policy learning[12].

Under the SI approach, the formulation of policies is based on existing theory (limited), indicators (limited) and subjective judgements (common sense). It is difficult for the policy makers to know ex-ante how the system will react to the policy. In a sense, as another building block of the system of innovation, policy is affected by the same systemic problems that were mentioned before. Particularly they are affected by cognitive and learning failures, that is, they might not have the ability to intervene or simply do not know how to do it (Bach and Matts, 2005). Policy makers need to experiment and allow some room for mistakes. For this reason, evaluation of policies is very important **[reference to chapter Polt].**

In other words, it is not possible to know for sure – ex ante – if public intervention can solve the systemic problem or not. The decision to intervene or not must thus be based upon whether it is likely or not that intervention mitigates the problem. Hence, the decision must be taken in a situation of uncertainty. Then one can afterwards – ex post – determine through evaluations whether the problem was solved or mitigated. If this was not the case, we are talking about a **policy mistake**. Policy mistakes can never be completely avoided because of the uncertainty mentioned. We must accept mistakes in public activity – as we do in private activities. Moreover, in order to be able to evaluate the success or failure of an specific policy, it is necessary to formulate clearly the objectives of the policy *ex ante*.

There may be various reasons why public intervention cannot solve or mitigate a problem. One is that it is not at all possible to solve the problem from a political level, that is, that the problem is out of reach for policy makers. It is an objective that might not be attained by any of the instruments available to the policy makers. Then all types of intervention would be in vain and result in a policy mistake.[13] The other reason is that the state might first need to *develop its ability* to solve the problem. A detailed analysis of the problems and their causes may be a necessary means of acquiring this ability.[14] The creation of new organisations and institutions to carry out the intervention might also be necessary. A particular body of knowledge may not be represented in the national

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[12] While the role of learning in a system of innovation has been extensively discussed by, among others, Jensen et al (2004), Lundvall (1992, 1996), Lundvall and Borras (1999), Archibugi and Lundvall (2000), learning processes in SI-based policy are still very much under-researched.

[13] Hence, the problem is not solvable by private actors or by public intervention.

[14] For example, it might be necessary to carry out a detailed comparative empirical analysis.

portfolio and require the establishment of a new research organisation or, a new policy instrument. Finally, the theoretical framework might be insufficient to understand the problems in the system.

It is important to note that a 'systemic problem' that motivates public intervention might concern the future. A 'problem' might be something that has not yet emerged. A '*problem-solving*' policy of this kind might alternatively be called an '*opportunity creating*' or anticipatory policy.[15] One of the problems to be solved might be that uncertainty prevents new technologies from emerging. One example of such a problem is the case where public funding of basic R&D might be necessary because capitalist actors do not have the incentive to fund it (e.g., because of inappropriability). Another example could be that training people in a certain field could create new opportunities that would not be realised without policy.

The discussion on policy intervention raises two important issues. First, policy intervention is specially needed when *uncertainty* and risk are very high and private actors do not find incentives to invest in those high risk products or new activities. Second, policy intervention needs to be *selective*, focusing on specific products, activities or technologies that better fulfil the (economic, social, environmental, etc) objectives of the government. The issues of uncertainty and selectivity will be discussed next.

3.2. Uncertainty

In the previous section we discussed the problems of the uncertainty related to the policy outcomes of an SI-based policy. In this section we discuss another type of uncertainty: the uncertainty linked to innovation processes, and the implications for the design of innovation policies. In other words, we argue that a high degree of uncertainty in the innovation process may be an important cause behind a systemic problem. This would then constitute a reason for public intervention.

Firms and markets perform less efficiently in a context where uncertainty and risk are large. Sometimes they do not perform at all with regard to them. As mentioned earlier, one of the "problems" to be solved might be that uncertainty prevents new technologies from emerging. For example, public funding of basic *R&D* might be necessary because private actors do not have the incentive to fund it or they might under-invest (Arrow, 1962) or they might even not invest in areas of great social return

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[15] There might be reasons to treat the solving of existing problems and the creation of future opportunities as two different kinds of situations calling for (different kinds of) public intervention.

but low individual return (e.g. some pharmaceuticals). Firms may also assume that *educating and training* shall be carried out by public organisations, and therefore they might not invest in human capital formation. In the very early stages of the development of new fields of innovation, there is uncertainty whether markets exists or not, and sometimes public organisations have been instrumental in *market creation* (directly, e.g. through public technology procurement, or indirectly, e.g. through regulation (creating or changing institutions). *Incubating activities* have been carried out in public or semi-public science parks to facilitate commercialization of knowledge in recent decades.

We have just mentioned four examples of "activities" (R&D, education and training, market creation, incubating)[16] where there are reasons for policy makers to intervene because uncertainty and risk are large and, therefore, private organizations weak or unwilling to act. As a matter of fact, innovation as such is plagued by uncertainty. Such uncertainty is often largest with regard to innovation in *new* fields of production. Although the discussion of uncertainty tends to be dominated by examples of new technology fields (where the uncertainty problem is more acute), uncertainty also affects mature sectors or small and medium firms. SMEs might lack resources (human capital, financial capital) and the information about innovation opportunities thus increasing their uncertainty about the innovation process. Policy makers might want to stimulate innovation in the system by addressing these systemic problems, providing incentives to innovation through capacity building and information provision.

Historically we have also seen that a minor public intervention in an early stage of the innovation process may have a very large impact.[17] Risks and uncertainty are largest with regard to the emergence of *new* products. This indicates that "systemic problems" are more common in such a context (but not exclusively as indicated before). It also seems to be an empirical fact that large-scale and radical technological shifts rarely take place without public intervention (as opposed to incremental innovations in established sectors). This has been indicated in Carlsson and Jacobsson (1997), where they go through the cases of electronics, semiconductors and genetic engineering in the USA and Sweden. David Mowery has also clearly shown that publicly funded R&D in combination with public technology procurement has played a crucial role for the development of new high technology sectoral systems of innovation in the USA (and thereby in the world). Some examples are the early phases of the development of numerically controlled machine tools, commercial

[16] We systematically discuss ten such activities in a policy perspective in Chaminade and Edquist (2006) and in Edquist and Chaminade (2006).
[17] The public support to the development of the NMT 450 mobile telecom standard in the Nordic countries is an example. The support amounted to a few hundred man-years.

aircraft, semiconductors, computer hardware, computer software, and the Internet in the USA. Hence, the innovation policy support to new products and sectors has been very strong in the USA. The objectives of this public innovation polices have often been of a military character (Mowery 2005).

Smits and Kulhmann (2004) suggest the use of what they call systemic instruments to cope what we call systemic problems. Systemic instruments do not focus on elements of the system but try to take the whole system, or at least part of the system into account. Two of these instruments are in particular associated with the uncertainty of any innovation process: supplying the information that the different actors need to define their innovation strategies (Strategic Intelligence, see Chapter Smits et al, Polt and Teubal et al) and providing the actors with the instruments, facilities and environments for experimenting and learning. This includes the provision of markets for new products (public technology procurement), the provision of incentives for research in certain priority areas (R&D incentives) or the provision of information, business services or capacity building to SMEs.

In sum, innovation involves a high degree of uncertainty and risk. The higher the uncertainty, the lower incentives private actors have to invest in innovations - and public intervention will be motivated.

3.3. Selectivity

We have argued that innovation policies should be focused upon solving or mitigating certain "systemic problems". This means that the policies cannot be neutral but are necessarily selective. When designing innovation policy, policy makers have to select not only the objectives of the policy (why to intervene) and the instruments (how to intervene), but also which problems to address by the intervention. Ideally, policies should be designed on the bases of a thorough analysis of the system, i.e. of how the system is operating and which the systemic problems to be addressed are. Such analyses should be based on systematic comparisons between existing systems of innovation (since no optimal system of innovation can be identified) (Edquist and Chaminade 2006).

However, in practice the final policy is often the result of not only the analyses of the system, but often also of ideology, of the imitation of policy "models" from other systems or of the influence from pressure groups (lobbyism) (Edquist and Chaminade, 2006). Lobbyists are special interests groups. They seldom find general subsidies or general support worth pressing for. Instead they often push for sector- and firm-specific public support, i.e. they enhance selective policies. Since lobbyists normally represent established interests and industries, they normally argue for policies supporting these established industries (for example, ship-yards, automotive and ICT) – and they are sometimes successful in achieving such public support.

One example indicating that innovation policy is generally selective is public investments in R&D. Analysis may reach the conclusion that x billion Euros shall be reallocated to research of relevance for the biomedical industry (from somewhere else). This is automatically a selective policy, since it favours the biomedical sectors of production and, more specifically the products and firms active in this industry – at the expense of others. The analysis of the system might also show that pharmaceutical companies are under-investing in R&D related to some drugs that might have an extraordinary social impact (e.g. a drug to cure malaria) but that are rejected by private companies in favour of more profitable drugs (e.g. Viagra). The government might decide to allocate funds to research in those socially needed drugs.

In both the cases of innovation policy formed by lobbyism (which is common) and strictly based on the comparative analyses of systems of innovation, the resulting policy is selective rather than neutral. However, in the two cases we might expect that policies are selective in different directions. For example, the identification of new sectors where uncertainty is large will not come as a result of lobbyism (as there is not yet a critical mass of lobby groups) but from the analysis with the purpose of identifying systemic problems. [18]

As Norgren and Hauknes (1999) argue one of the basic choices that policy makers need to make is between strengthening existing systems and facilitating the creation of new systems. In general, we argue that government support is most needed when uncertainty and risk are high and there is a risk that the private sector will not act - thus neglecting opportunities for change and renewal. Such support to new activities and products can encourage the emergence of brand new sectors as well as support to the transformation of more traditional sectors by supporting their adoption of new products and processes. The focus should be on supporting new products (goods as well as services), new processes (technological as well as organisational) and they can be in new or existing sectors. Furthermore, it should be noted that support might be needed for the emergence of a new product or process but also for the dissemination of it, for example across sectors. This is especially relevant for generic technologies whose wider dissemination might increase the number of applications through complementary innovations.

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[18] There are reasons to limit the degree of selectivity in innovation policy – and maybe accept it only for sectors and products in *very* early stages of their development. However, this must be analyzed in more depth in future work. Then a distinction could be made between selectivity with regard to sectors, products, activities and firms respectively.

The issue of selectivity needs to be further discussed in relation to different kinds of systems of innovation: sectoral, regional and national

Policies targeting *sectoral systems of innovation* tend to aim at promoting specific sectors that are considered crucial for growth (or some other policy objective). Whether policy makers should select new and emerging sectors or support new activities and products in existing sectors is still subject of a hot debate among academics and policy makers. In reality, what most governments have done is to chose a combination of emerging new sectors (Bio-tech, ICT, Nano technologies) with other sectors deeply rooted in the country's economic structure (transport or materials).

Policies aiming at *regional innovation systems* are basically concerned with the growth of a specific region and its integration in international markets by means of mobilizing "all relevant players involved in the process of becoming internationally competitive within specific areas of growth" (Vinnova, 2001:5). Government intervene to 'create' or develop the regional system of innovation, by facilitating the interaction between the different actors and the development of a common growth strategy.

Finally, policies aiming at *national innovation systems* often aim at generating national competences for learning and growth (competence building) and are concerned, for example, with the development of a skilled workforce, a strong research capacity, etc.

3.4. Inertia or path dependency in policy making

Finally, it is important to note that a systemic innovation policy brings together a variety of policies that have traditionally been separated (education policy, industrial policy, etc). In this sense, innovation policy can be seen as a (policy) system itself, integrating traditionally individual and independent policies into a new systemic policy with new rationales, new (systemic) instruments and new governance bodies. Adopting the SI approach implies the adoption of new rationales that might collide with former rationales. In other words, policy makers might adopt the system of innovation approach in their discourse while still using "market failure" arguments for allocating resources for innovation.

One way to overcome this path-dependency is to create new government structures or organizations responsible for the design, implementation and evaluation of innovation policies that explicitly adopt a system of innovation approach for policy-making One example of this is the case of VINNOVA in Sweden (see chapter **XXX- Carlsson).**

4. CONCLUSIONS

In this paper we have tried to discuss rationales for public intervention based on neoclassical theory and on the systems of innovation approach. We have argued that governments should intervene when a **systemic problem** that is not spontaneously solved by private actors exists, i.e. when private actors do not achieve the objectives. Furthermore, the public agencies must have the ability to solve or mitigate the problem.

We have argued that innovation policy is normally, and should be, selective. The crucial question is in which **direction** the policy is selective and whether the choice of direction is based on lobbyism or on a rigorous analysis as a basis for designing the policy. We have argued that the selection should also be made on the bases of a rigorous analysis of the system of innovation – which has to be empirical and comparative between existing systems. We have also argued in favor of prioritizing those areas where there is a greater degree of uncertainty and risk or where the collective returns might be very high (for example in environmental or social terms). This is an important issue for further analysis. Such an analysis of directions of selectivity could preferably make a distinction between selectivity with regard to sectors, products, activities and firms respectively.

In all policy-making one has to accept that mistakes are being made – just like in private activities. Policy makers are embedded in the system of innovation and, as such, they are subject to systemic problems, including the lack of capacity to identify a problem or the lack of information or knowledge on how to solve it. In this sense, policy learning becomes a fundamental element in innovation policy and the continued interaction between academia and practice, in this sense, between researchers and policy makers is not only recommendable but necessary.

More research is needed in collaboration with policy makers. It seems clear that the discussion on the rationales of policy intervention is rather theoretical. It is important to acknowledge that policy making is not always a rational process (rationales are often sought after the decision has been taken). The rationale emerges as a result of an ex-post analysis and not as *a priori* exercise (Elg, 2006)

Furthermore, discussion up till now has been at a rather general level. More research is needed on the impact of the adoption of the system of innovation approach in relation to specific policies or instruments, such as IPRs, the support of university-industry relationships, etc. That is, we need to zoom in and discuss how these institutions and relationships of the system should be dealt with when policy makers adopt a SI approach. More insight into the dynamics of the system are a necessary precondition for this (see chapter by Jacobsson, Smith and Hekkert). In this context also the development of instruments that take (parts of) the system into account, instead of instruments that focus on elements of or bilateral relations in the system (as is is the case now), is necessary (see: chapter Teubal, Smits & Kuhlmann)

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