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CONCEPTUALISING A NATIONAL INNOVATION SYSTEM: ACTOR ROLES AND INCENTIVES

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Abstract

This paper presents a conceptualisation of a National Innovation System (NIS) consisting of dynamic Science Technology and Innovation (STI) actors operating in the backdrop of a set of supportive social technologies (institutions). The presence of institutions that are compatible with the workings of a NIS is a necessary but not sufficient condition for its sustainability. We highlight the different roles STI actors perform within the system, thus enabling an understanding of their contributions to the system’s innovative capacity. Normative policy that hopes to influence such contributions will need to be informed by actor-specific motivations for engaging in innovation-related activities and for collaborating. We argue that it is STI actors that drive the innovation system forward, so their underlying motivations are ultimately conditioning its sustainability. Building on the NIS approach, the paper proposes an incentive-based analytical framework. The proposed STI actor roles and analytical framework constitute a viable platform for future empirical analysis.
1. Introduction

The economy’s ability to communicate and assimilate existing innovations as well as generate original ideas is now seen as central to improving efficiency, maximising output and increasing employment. The communication of ideas and the occurrence of learning within the economy are important prerequisites for innovation. Country-specific conditions could affect the degree of communication and the likelihood that learning will lead to original innovation. The National Innovation Systems (NIS) approach, underscores the importance of sustained links between actors engaged in innovation, in the backdrop of a supportive institutional environment.

We begin by exploring the emergence of the NIS approach and we outline its basic assumptions. A review of literature yields a stylised view of a NIS; the underlying processes, prerequisite institutions and science technology and innovation (STI) actors that facilitate ever-increasing levels of innovative output. A key question is the extent to which the production of new ideas within the system is sustainable. The presence of institutions that are compatible with the workings of a NIS is a necessary but not sufficient condition for its sustainability. Therefore, a primary area of interest is the identification of actor-specific motivations for engaging in innovation-related activities and for collaborating. We argue that it is STI actors that drive the innovation system forward, so their underlying motivations are ultimately conditioning its sustainability. Taking into consideration the different roles of STI actors we propose a general analytical framework for interpreting STI actor behaviour, based on incentives. Ultimately, an
understanding of STI actor incentives could assist policy toward putting in place institutional instruments leveraging innovation.

2. Emergence and Rationale

Solow’s and Mansfield’s work in the 1950s and 1960s demonstrated the centrality of the generation (innovation) and spread (diffusion) of new ideas to the process of economic growth. The technological developments of the second half of the twentieth century and the resulting shift in the pattern of production led many to talk about the emergence of a new techno-economic paradigm. Innovation was no longer confined to the sidelines of economic activity but rather its influence was becoming ubiquitous. This is evident in the theories of Bell (1973) who in many respects foresaw the social consequences of modern technological innovations and talked with remarkable prescience about an ‘information and communication technology revolution’. Rosenberg (1976) too identified differing levels of access to existing technology as the main cause for the divergent economic paths of developed economies and the rest of the world. The apparent correlation between economic prosperity and innovative competence carried an implicit policy suggestion; the support of basic science and its transcendence from intangible knowledge onto relevant, productivity enhancing products and services. This view was further reinforced by the increased relevance of international trade in technological products and services. The commoditisation of technology led to it being increasingly seen as something that not only could be traded but could also be produced, if only sufficient resources were
devoted to it. One could now reach an obvious logical conclusion; if knowledge is a commodity then surely the same principles that apply to a Fordist vertical supply chain could be applied there too. Such a conceptual approach to the production of knowledge is often termed the linear ‘model’\(^1\) of innovation (Freeman, 1995).

However knowledge and certainly the generation of new knowledge hardly fit such a linear view. Unlike the other forms of production, generating new ideas may also be motivated by non-economic motives, curiosity among them (Mokyr, 2002). Whereas allocating resources to research and development might generate knowledge there is no guarantee that its innovation output will be relevant or that it would benefit the whole of the economy evenly. The sequential nature of innovation also means that a critical mass of accumulated knowledge is necessary for the production of further knowledge. New-to-world innovations are only possible when the backlog of related past technologies has been successfully assimilated. Access to the body of past knowledge will also depend on technology transfer from international pools of knowledge. Transferring, creating, diffusing and accumulating knowledge goes beyond the scope of basic research; it calls for a comprehensive supportive system. Lundvall’s (1992) book on “National Innovation Systems” was one of the first modern attempts to analyse the systemic mechanisms of innovation creation and its subsequent effects within a national context. The basic premise of the approach is that innovation matters can be better explained when one

\(^{1}\) While there is broad agreement among innovation theorists that the linear model is inappropriate, there is scant evidence that such a model was ever seriously proposed as a coherent theoretical framework. Mentions of a linear model in literature are mostly attempts to convey underlying assumptions by policy makers during the 1960s. Its frequent mention in literature may also stem from the fact that, by contrast, it helps to illustrate the potency of systemic approaches.
views the economy as a system comprising of distinct elements and interprets the causes and effects of both their actions and interactions.

A technical metaphor would be fitting to a first description of such an intricate system. One may ponder the institutional framework currently in place in developed societies (with targeted investments in education and infrastructure, legal and regulatory structures, prevailing cultural attitudes and a network of STI actors to drive innovation) and the extent to which it resembles a complex mechanical apparatus. This ‘machine’ owes part of its existence to autonomous economic and social evolution and part to inspired craftsmanship. One could extend the metaphor further and think of a NIS as an ‘engine’ of knowledge creation and transmission, whereby innovation actors and inter-actor linkages can be likened to a set of harmoniously operating cogwheels laboriously contributing to the engine’s performance and – at the same time - acting as conduits for the dispersion of its energy. Like elaborate mechanical clockwork a NIS has the ability to accelerate a country’s innovative performance and by means of systemic linkages perpetuate this growth – limited only by the capabilities of its constituent parts. Over time, even these limitations are redefined by cumulative learning and the resulting increase not only in the stock of knowledge but essentially in productivity. Furthermore, the system does not operate in isolation but is in communication with similar systems elsewhere; parts of this mechanism are driven by investment and output that are sourced from and directed abroad.
While the concept of a ‘national innovation system’ is relatively new\(^2\), in a broad sense the study of direct and proximate causes of economic development within the confines of the nation state is hardly original. The NIS approach’s fascination with evaluation on a cross-country basis and the casual portrayal of national economies as entities in head-on competition with one another is reminiscent of nationalist economic theories. However, unlike such views focusing on autarky and protectionism, NIS approaches recognise the importance of increased international embeddedness and elevate it into a central determinant of national economic performance\(^3\). Therefore in NIS literature the term ‘national’ is used as an indication of scope rather than as a suggestion of an aim to seek national ascendancy. Lundvall (1992) justifies the national focus by virtue of the characteristics of nation-states. Though he grants that single-nation states are the exception rather than the rule he proposes that the national scope is relevant to countries, which are usually small, “culturally homogenous”, are “controlled by a single central state authority”, “gathered in a single geographical space” and are “socio-economically coherent” (Lundvall, 1992: 3). Perhaps most important of all is the fact that institutions that condition broad social rules and the particular rewards for innovation have national limits.

There are two main assumptions attached to the analysis of an innovation system at the national level. The first has to do with the value the NIS approach places on cooperative

\(^2\) Introduction of the concept is frequently attributed to Freeman on an appraisal of Japan’s innovative performance though the first mention of the exact term “national innovation system” can be traced to Lundvall’s 1992 analysis of innovation in the Danish economy (Lundvall, 1992).

\(^3\) International embeddedness can influence national innovative (as well as economic) performance by means of international trade (trade in capital goods, embodied technology transfer), the international mobility of skilled labour and FDI spillovers.
relationships and knowledge flows. Implied in this value is the assumption that innovation can be fostered by inducing ‘more’ knowledge flows (entailing collaborative linkages, technology diffusion and human resources mobility). The second assumption is that the impact of further knowledge generation and technological development is moulded by existing political, social, economic structures and even cultural norms (Patel and Pavitt, 1994; Edquist, 1997; Nelson and Sampat, 2001). In turn, the NIS approach places great faith on the ability of existing institutions to influence the generation of knowledge and achieve economic success.

One can almost certainly attribute the popularity of NIS to its ability to provide policy direction in an era when the rapid pace of technological development has added new importance to innovation not only as a factor of production or as a key commodity but also as a powerful force in shaping economic order. Therefore, the unique advantage of the approach stems not from a totally novel insight into economic dynamics but from its capacity to explain how recent technological developments affect economic structure and output. The NIS approach owes this advantage to the fact that it is an empirical framework that emerged through the observation of actual evolutionary trends rather than a priori assumptions. The influence of evolutionary economics is also apparent in systemic rhetoric on ‘selection mechanisms’ (Carlsson, 1995; Edquist, 1997; Etzkowitz and Leydesdorff, 2000) and its tendency to emphasise the historical perspective (Freeman, 1995). In accordance with evolutionary theory, most systemic approaches also represent a departure from the neo-classical view of profit-maximising agents, not least because of the importance they place on agents who are not motivated by profit.
(government, academia and in some cases NGOs). The broad level of analysis means that the NIS approach incorporates rationalities that are not strictly economic but also political and social. The fact still remains though, that economic processes and their underlying efficiency are the major drivers of innovation and its collaborative arrangements.

At this point it is important to make a clear distinction between broad national technological competence and a NIS. National technological competence, that is, an improved nation-wide ability to create, transfer and assimilate innovations as well as extract benefits from the use of new technologies, is ultimately where the broad range of innovation-related economic benefits stem. A NIS is merely a means to an end rather than an end in its own right. Throughout the paper it is maintained that the encouragement of specific systemic interactions should depend on their ability to meet this end.

3. Characteristic Processes

A fundamental distinction exists between knowledge that is *codified* in a referential form (e.g. books, blueprints, patents) and *tacit*, operational knowledge obtained by individuals as the result of ‘learning by doing’. Lundvall (1992) recognises that *knowledge* is the single most important resource in the modern economy. By extension, overall innovative competence hinges first and foremost on the economy’s ability to accumulate knowledge, whatever its form, by means of *learning*. Continuous learning, just as innovation, cannot
be achieved in isolation; as Lundvall (1992) points out learning is a social activity, which inherently depends on an agent’s embeddedness into a social system. The economy, as a social system characterised by implicit communication between producers and consumers, lies at the heart of a NIS.

Learning facilitates the communication, diffusion and accretion\(^4\) of a stock of sequentially depended innovations. Importantly, learning improves the technological scanning abilities of actors making the timely adoption of appropriate technologies more likely. Many of the benefits emanating from the presence of a comprehensive set of interlinked actors are not simply the result of learning but of *interactive learning*. Interactive linkages gear actors towards structures that make them better capable of meeting each other’s needs. It is interactive learning, and its ability to promote organisational dynamism that makes a *system* the socially desirable arrangement of innovation elements. According to Lundvall (1992) interactive learning has the indirect consequence of yielding outcomes transcending neo-classical rationality. Granted, private firms may, at least initially, be motivated solely by the desire to maximise profits. However, given enough time, and particularly since many of the actors in the system do not operate under a profit motive, relationships may emerge that cannot be accurately explained under a rational light. Through this inherently evolutionary process, social and cultural norms emerge such as trust, the willingness to cooperate and a tendency towards reciprocation.

\(^{4}\) As Young (1995) showed in his empirical study in East Asian economies, the dissemination of new ideas, methods and capital goods has a cumulative effect on factor endowments, with a corresponding effect on economic growth.
Indeed, the consequences of interactive learning mean that innovation systems are more than the sum of their constituent parts; Lundvall (1992) argues that actor linkages and associated social learning exhibit dynamic characteristics; constant communication makes actors prone to change while associated incentives accelerate the pace of innovation. Linkages are conducive to the spread of not only technological information (about the availability and uses of new technology) but, importantly, of market–related information. From a firm’s perspective, such information may have to do with the qualities of competitive offerings. This kind of information enables participating firms to recognise market needs and direct applied research towards meeting them. The profit incentive not only provides leverage for innovation, but effectively information obtained through market transactions, places firms in a better position to harness the commercialisation potential of new technologies. In addition, competitive pressure, even when it is remote, adds to the urgency for innovation output. The presence of linkages between producers and users of the technology increase the potential for its widespread diffusion and consequently the possibility of profit maximisation. This results into what Lundvall (1992) calls “positive feedback”; the pace of innovation speeds up as innovating firms are motivated by further profits5 and at the same time, have more funds available to make it happen. Prolonged experience with feedback cycles means that cumulative learning further improves their innovative capacity and increases the market relevance of their innovative output.

5 If one also assumes the presence of a patent system, then actors are also motivated by the need to retain their temporary monopoly.
In a NIS, linkages with other actors engaging in innovation or having an interest in its outcome are important channels for codified (and to a lesser extent tacit) knowledge flows. Collaboration among STI actors has been shown to have positive effects on innovative activity (Caloghirou, Vonortas and Ioannides, 2003; Belderbos, Carree and Lokshin, 2004). Specifically, inter-firm, inter-organisational linkages and their combinations are the ones with the most significant contribution to learning and output at both the national and international levels (Mansfield, 1964; Baranson, 1970; Rosenberg, 1976). Freeman (1995) sees the emergence of dedicated R&D departments within firms and other specialised R&D centres as pivotal to the modern evolution of NISs. It appears that sometime during the nineteenth century the pace of technical change and the demands of expertise specialisation meant that lone inventors lost their pre-eminence as the major innovators. As is common today, invention became the product of the collective efforts of many dedicated groups of individuals. As a consequence, systemic approaches define innovation actors as synonymous to organisational entities and tend to pay little attention to intra-organisational processes.

In their most basic form, inter-actor linkages may materialise as user-producer relationships. They may involve market transactions or even direct innovation funding (e.g. through subcontracting or donations) and due to their nature are more likely to result in the transfer of codified knowledge. Further to the effects of market transactions collaboration linkages act as conduits for spillovers of both codified and tacit knowledge.

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6 As Mokyr (2002) illustrates, the socialisation of innovation came about as a response to the need for sustained innovation, as opposed to the one-off improvements characteristic of earlier times; the need itself driven by the emergence of technological markets afforded by industrial production and the incentives provided by institutions.
Joining forces facilitates innovation as more resources are devoted to specific R&D projects. Importantly not only costs are shared but the associated risks too. It also increases the probability that ‘chance innovation’ of broad appeal may occur. Linkages that are sustained over long periods, inevitably improve the learning capabilities of participating actors. Inter-actoral co-operation can have positive long-term effects on the interactive capacity of an actor by ensuring compatibility of operational structures and by inducing the adoption of interoperable techniques, approaches and technologies. Learning about the needs of other actors with essentially different characteristics and motivations makes it more likely that any resulting innovation is relevant for the wider economy. Engaging in linkages improves the chances that the actors will become aware of the availability of a greater number of innovations (otherwise termed ‘diffusion of information’) and, by way of learning, accumulate a stock of past knowledge. Since the production of new innovations explicitly depends on the body of existing innovations (only a fraction of which will be familiar to any given STI actor), systemic linkages increase the actors’ familiarisation with the existing stock of technology and thus increase the probability of new-to-world innovations materialising. The diffusion of information may also enable the introduction of an existing innovation into a novel contextual setting (local market, industry niche). What applies to the national level is also true across borders; linkages among foreign and domestic firms have been shown to result in international technology transfer (Baranson, 1970; Blomström, 1989).

Systemic linkages though are not the only channels of knowledge flows. Tacit knowledge may also be transferred by either the movement of personnel or by the diffusion of
technological equipment or processes. Lundvall et al. (2002) highlight the importance of labour market dynamics for the organisation of knowledge creation and learning within firms and in networks. A numerous and skilled supply of labour is essential for the absorption, transfer and creation of further knowledge (OECD, 1997). The level of growth in the supply of human resources for science and technology is the ultimate ceiling for NIS growth. Accordingly, demographic trends, including the international immigration of skilled labour have positive effects on this supply. Moreover, the level of education and associated skills determines the effectiveness of learning and is thus vital to the absorption of tacit knowledge and its consequent transfer.

As far as tacit knowledge flows are concerned, the mobility of personnel across firms, geographic localities and professions is a key channel (OECD, 2001; Hauknes and Ekeland, 2002). Crucially, when individuals move, they carry tacit knowledge learned previously; at the point of destination this often translates into productivity enhancing process technologies, either intact or in combination with the knowledge stock they encounter. The propensity of staff to move across organisations is seen as a crucial factor in the creation of long-term linkages; established working relationships within an organisation may translate into interactive linkages across organisations. Additionally, movements of staff between innovation performers and innovation funders have the ability to cross-fertilise thinking in organisations; researchers moving to industry know what is feasible and researchers moving from industry know what is marketable. There are however limits to what can be achieved by redistributing available human resources, especially since the movement of staff implies a loss for the originating organisation.
Despite such loss, provided the conditions within firms are ripe for learning, mobility may end up yielding a net positive effect to the originating organisation. The assumption being that labour in transit would have passed on knowledge to the organisation’s remaining labour stock.

The diffusion of technological equipment also leads to knowledge flows. That is a quite distinct effect to the direct productivity gains traditionally associated with their diffusion (Rosenberg, 1976). Tacit knowledge about specific technological processes (how the machines work) and their usage (how the machines are operated) is transferred at the point of use. Effectively, technology that is embodied in intermediate and capital goods spreads as a by-product of their diffusion. Such positive externalities or spillovers are especially relevant as a measure of knowledge flows between producers and users of a technology. In a study of 10 OECD member countries, Papaconstantinou, Sakurai and Wyckoff (1998) found that while innovations emerge in R&D intensive manufacturing clusters, it is services sector industries that are the main acquirers. Thus, diffusion-incited knowledge flows may result in innovations that are new to a particular industrial or geographical niche as well as enhance the prospects of future diffusion cycles.

4. *A Stylised National Innovation System: Institutions*

Systemic interactions can only be permitted to flourish, given the presence of a set of institutions to support the system and maintain appropriate checks and balances within it. Conversely, Lundvall (1992) argues that the existence of ineffective institution
“constellations” can result in a combined retardant effect. The example of the Soviet Union is used by Freeman (1995) as a situation to be avoided. Frequently, the term ‘institutions’ is used as a heading for all residual elements the workings of which do not have an explicitly stated STI role. In the interest of clarity we adopt here the view of Nelson and Sampat (2001: 40) in thinking of institutions as social technologies that have come to be regarded as a regular feature of the national economy. In that respect, institutions are seen as passive elements, which STI actors are habitually accustomed to and take for granted. The development of such institutions, be they tangible in the form of supporting organisational arrangements and codified laws or intangible such as cultural norms and conventions is inherently path-dependent and thus of great interest to a study with a national scope.

First of all, an efficient education system contributes to the development of a competent science base, manifesting itself in the numbers of highly skilled scientists, engineers and active researchers. Of relevance here are the extent to which the educational system meets the demands of the market and the values it attaches to matters of science, technology and innovation. An educational system encompasses more than official arrangements for schooling, as it includes prevalent attitudes to knowledge and education. For instance, cultural norms pertaining to intellectual aptitudes are also significant; valuing authority and mnemonic skills over critical ability contributes to a perception of knowledge that is static, hardly conducive to innovation. An institutional

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7 Its input-centred mode of governance created ample opportunities for rent-seeking. An institutional arrangement where personal liberties and democratic accountability were absent promoted a particular kind of innovation (military) at the detriment of others and obstructed knowledge flows.
arrangement that encourages the optimal allocation of human resources for science and technology (in terms of professions, levels of expertise, geographic localities) is crucial.

Moreover, the presence of conditions that make financial capital for risky ventures readily available also nurtures an innovation system. As the fruits of innovation typically take time to mature, a competitive and efficient financial sector can provide much needed capital for maintenance. Conventional thinking has it that macroeconomic stability, manifesting itself in stable or at least predictable interest rates is also an important determinant of investment. To contrast with, Christensen (1992) points to the irrelevance of interest rates in the context of technological investment. Christensen’s reasoning is that high-risk investment ventures are, as a rule, not forestalled by high interest rates, as they are motivated by high expectations of return. Conversely, Christensen (1992) argues that the governing mechanisms of financial markets and more specifically borrower-lender relationships based on mutual trust influence lending decisions and have thus a far greater impact on the availability of financial capital. Closely linked, is the availability of venture capital which hinges not only on the presence of trust but also on confidence on the ability of firms to bring their plans to fruition.

Issues relating to polity and social organisation affect directly the spread of knowledge and create incentive mechanisms for invention. For one, a democratic political system, with its characteristic checks and balances may reduce transaction costs to a level that approximates efficiency (North, 1990). The influential work of Barro (1996) highlighted the link between personal liberty, entrepreneurial freedom and economic growth. It
comes as no surprise then that the sheer number of original ideas is greater in societies valuing democratic pluralism. A degree of social uniformity and cohesion within the defined political unit (e.g. the nation-state) may reduce the effects of rent-seeking and could, given the right conditions, assist the emergence of consensus politics.

Then again, totally unrestricted knowledge flows may impose very serious social costs. There exists a fine distinction between what constitutes socially beneficial ‘diffusion of ideas’ and what could be rightfully construed as rent-seeking. The public-good nature of innovation necessitates an artificial reward mechanism to compensate the inventor’s investment and induce innovation. This materialises in the form of intellectual property rights (IPR) and their innovation-specific incarnation; patents. The provision and enforcement\(^8\) of property rights in general and patents in particular is central to a developed, productive NIS (Patel and Pavitt, 1994). Patenting though is no panacea in itself; carefully defining what is patentable and how long a monopoly should last while making provisions for fields of knowledge that are not motivated exclusively by profit (e.g. free and open-source software) is equally crucial. Whereas patents motivate innovation, high industrial concentration could stifle innovation, as technological leaders seek to maximise the yields of their knowledge stock (Arrow, 1962; Geroski, 1994). It is interesting that while NISs have social technologies in place to cater for oligopolistic technological collusion (within the broad confines of antitrust legislation), social technologies to tackle monopolies are still lacking.

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\(^8\) There are arguably cases where the lack of enforcement of patent laws may facilitate international technology transfer. In this capacity, developing countries (where new-to-world innovations are less likely to be invented) may tolerate IPR breach as a form of subsidy to infant industries.
A further requirement is that the system has been in place for sufficient time for its contributions to be felt in the economy. This is what Carlsson and Stankiewicz (1997) refer to as achieving a certain density or “critical mass” which includes physical resources (e.g. finance), human capital (e.g. level and appropriateness of skills, labour mobility) and accumulated knowledge. Carlsson and Stankiewicz (1997) argue that critical mass is related to the clustering of resources in a particular geographic area or industrial sector. Sectoral clusters are valuable in their own right as they signal international comparative advantage in a particular sector. Concomitant to the clustering of resources is the existence of substantial entrepreneurial interest in any given technical field. The experimental and unpredictable nature of the innovation process means that numerous attempts (some successful and a great many unsuccessful) are necessary before a cluster emerges. Linkages, particularly those between scientists and entrepreneurs, can prove critical to the success of such ventures in technological markets.

Providing adaptive policy solutions to institutional failings falls under the wider framework of improving national innovative competence. Establishing and maintaining institutional arrangements conducive to the dynamic efficiency of the economy is one of the key functions of government. Technical change and factor uncertainty means that economic structure is in a state of constant flux. There is no guarantee that institutions that are functioning at present will continue to do so indefinitely. Systemic linkages and related interactive learning make policy makers more responsive and more innovative in their prescriptions. Different countries use different mixes of institutional arrangements and policies. By incorporating institutional and policy differences into an explanation of
innovative and economic performance, the systems of innovation approach helps us explain why such differences among market economies matter. It allows us to identify bottlenecks and perverse institutional incentives, which may be inhibiting an economy’s innovative potential. The way in which institutions are designed and their willingness and ability to co-evolve with technology will influence how well different systems perform in generating and selecting innovations.

5. A Stylised National Innovation System: STI Actors and their Roles

Supportive institutions are important prerequisites for an effective innovation system but their presence will not necessarily spur innovative output. Ultimately, dynamic STI actors are the drivers of the innovation process. The outcome of innovative processes is not affected solely by actors who are directly involved in R&D but also by those who fund, lobby for and use its products. These are typically aggregated in three broad sets of STI actors:

(a) government (and other public sector) bodies;

(b) industry (firms or individual entrepreneurs);

(c) academia (universities and research centres).

The bundling of STI actors into the convenient realms of government, industry and academia is frequently referred to as the “Triple Helix of Innovation” (Etzkowitz and
Leydesdorff, 2000: 111) a term designed to evoke evolutionary connotations and underline mutual dependence. Although theoretically distinct, the three are in practice less neatly distinguished. A characteristic that is common among them is that innovation is not an exclusive strategic target which STI actors unfailingly dedicate resources to but may often be an activity removed from the core of their operations. STI actors often exhibit overlapping responsibilities and utilise common pools of resources. At the same time they have very different roles within the system and are motivated by discrete incentives.

To draw again from the ‘engine’ analogy, each of the STI actors could be likened to the engine’s component parts; a NIS comprises of various subsystems, where STI actors have a key role. Importantly, the role of each component part is different so their contribution to the engine’s performance can only be measured by taking into account their distinct role. STI actors also have different roles and sometimes divergent motivations for their actions. Categorising STI actors according to the capacity in which they act enables an understanding of the dynamics of the system. It also allows for capturing in an all-encompassing analysis the distinct rationalities of policy, market processes and network arrangements.

It is common practice in policy-oriented documents (OECD, 1997; Forfás, 2004) to place STI actors into the two broad categories of innovation funders and innovation performers. Andersen (1992) and Lundvall (1992) distinguish actors into technology users and producers. They are the most important elements in the system having by far the greatest
impact as their actions are ultimately governed by market forces. Policy makers too play an instrumental role by providing overall direction and devising measures to advance innovation. Policy makers can strive to ensure that market forces operate unobstructed by regulating competition and rewarding innovative output through the provision of property rights. In that sense, policy makers are the actors with the most direct effect on a country’s institutions. Long-term technology policy can make a difference by fostering a supply of highly skilled labour and adequate public infrastructures. The beneficial role of policy makers is contingent as much on their decisions to refrain from intervention as it is on their prescriptive responses. Very often though the success of their policies hinges on the efficiency of public sector bodies charged with carrying out policy, which we choose to term policy enactors. This is where a flexible and honest public sector apparatus can make a difference. Important information flows about the direction of inventive activity (including specialist advice, calls for funding and market signals) emanate from a distinct set of actors, which we choose to call technology lobbyists. Technology lobbyists fulfil a vital feedback role, complementing market signals between users and producers. Table 1 presents the common types of STI actors along with the capacities typically associated with each set. Notice that each set of actors and even each individual actor may act in one or more capacities.
Table 1 – STI actors and their capacities

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<tr>
<th>Types of STI Actors</th>
<th>STI Actor Capacities</th>
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<tr>
<td><strong>Government</strong></td>
<td></td>
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<tr>
<td>-  top-level government</td>
<td>policy makers, policy enactors</td>
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<tr>
<td>-  other public sector bodies</td>
<td>technology lobbyists, technology users, technology producers</td>
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<tr>
<td><strong>Industry</strong></td>
<td></td>
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<tr>
<td>-  indigenous enterprises</td>
<td>technology producers</td>
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<tr>
<td>-  multinational enterprises</td>
<td>technology lobbyists</td>
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<tr>
<td>-  investment banks</td>
<td>technology users</td>
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<tr>
<td><strong>Academia</strong></td>
<td></td>
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<tr>
<td>-  universities</td>
<td>technology producers</td>
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<tr>
<td>-  research centres</td>
<td>technology lobbyists, technology users</td>
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Figure 1 presents an arrangement of STI actors according to their role in the system. Technology users and policy makers (STI funders) provide the necessary resources for innovative activity. Innovative activity is carried out by technology producers and policy enactors (STI performers), producing innovation outputs. In turn, technology producers, technology users and policy enactors also act as technology lobbyists, providing valuable information back to policy makers. This way they perform a vital feedback function, which depending on the presence of critical mass, could have institution-shaping consequences. Technology users also lobby directly technology producers, by way of implicit market signals. In no case is lobbying initiated independently but only arises as the by-product of engagement in the system under a different capacity.
Hence, STI actors perform different functions, motivated and confined by the institutional arrangements prevalent nationally.

6. *From Innovation to Collaboration: An analytical framework*

The NIS approach provides a solid basis for an understanding of the mechanics of structural and technological change. At the broad macro-level, the identification of selection mechanisms, as provided by an evolutionary framework, is useful at explaining how change occurs. It gives little insight, however, to the underlying causes triggering particular instances of change (Mokyr, 2002). An analytical framework that is compatible with the empirical observation of causal effects will inevitably need to look at actor-specific incentives.
The nature and extent of involvement in the NIS of each of the broad sets of actors (industry, government, academia) is motivated by correspondingly different sets of interests. Understanding these motivations is tantamount to understanding the driving forces behind both linkages and innovative output. In an ideal situation, STI actors would organise themselves into productive hybrid networks harnessing the maximum potential of knowledge flows and associated learning. However, this cannot happen in the absence of sufficient leverage. Such leverage lies with incentives and threats conditioning the strategic decisions of STI actors. The feedback process is driven by various sets of subdynamics existing in complementary and/or competing relationships to one another.

STI actors have varying incentives for funding innovation, engaging in R&D and seeking out collaborative linkages. Bounded by capability and information constraints they go through a two-step decision process (Figure 2). At first they must decide whether it is in their interest to engage in funding and/or performing innovation at all. If they deem their resource investment to be worthwhile they then ponder whether it would be in their interest to do so alone or share the burden with another STI actor. The second step involves a weighing of innovation costs and risks, particularly individual opportunity costs for accessing a specific knowledge area, against the benefits of maintaining exclusive access to the present and future knowledge stock. In an ever-changing system the results of the innovation process feed back to alter the subdynamics of STI actors. Importantly the motivations conditioning each actor’s decision to innovate and network cannot be considered static but must be determined on an ad hoc basis.
Notwithstanding their changing nature, they also possess basic underlying qualities that change little over time allowing some generalisations to be made. As far as government is concerned for example, one could argue that technological competence is an end in itself. It is sought though mostly to the extent that it can contribute to economic growth in general and the creation of employment in particular. The creation of jobs also ranks

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9 The government is, by far, the actor most likely to invest in basic research even when the prospects of its commercialisation are remote. Such action is undertaken as a response to perceived 'market failures', in areas where there may be long-run social benefits but bleak immediate individual pay-offs.
high among the concerns of the electorate and this may make governmental actors more inclined towards promoting those aspects of the system that would secure employment even to the detriment of long-term growth and international competitiveness. This does not have to be a conscious choice on the government’s part; it may simply be that those choices that appear to have the most immediate positive effects on employment are taken, with little consideration or understanding of wider implications.

Edquist, Hommen and McKelvey (2001) performed an exhaustive analysis of the ways in which innovation impacts on employment. They argue that product innovations generate demands on production which have a positive effect on employment. Contrarily, process innovations improve on productivity by substituting capital or labour and, as a rule, impact negatively upon employment. Utilising empirical evidence from a number of OECD countries, Edquist, Hommen and McKelvey (2001) show that the generation of product innovations increases employment and that productivity rises (associated with process innovations) can lead to unemployment. If the above were true, one would expect government to be biased towards the production of product innovations. When the factor of time is considered though, the increased cost-effectiveness stemming from process innovations could stimulate demand (assuming certain price elasticities) and as a consequence affect employment positively. Under such a scenario, failing to invest in the generation of process technologies could then impact negatively upon a national system’s competitive position in technological markets. Hence, a competitive innovation system would generate a healthy mix of product and process technologies, or alternatively possess secure ways for their transfer from abroad.
In modern innovation systems private firms are major innovators because there are devices in place to reward their efforts. Firms and individual entrepreneurs engage in innovation motivated by profit seeking and the potential temporary monopoly a registered patent could grant them. At the same time they have to weigh expected profits against not only financial but also opportunity costs. Arrow (1962) has shown that in the absence of competition, firms may prefer to devote all their resources to the production and provision of existing goods and services rather than engage in innovation. On a survey of 14 EU countries, Faber and Hesen (2004) found a positive correlation between patent output and product innovation sales. Motivated and enabled by greater sales firms are further encouraged to both innovate and protect their ideas. There are also time-, event- and path-dependent motivations for which any generalisation is of limited value. For instance, industry may engage in research in response to very specific intra-firm operational problems. Innovative efforts in a particular sector may increase when there is a perception of potentially very great benefits for only an incremental innovative step. Inter-firm and inter-organisation collaboration in innovation is less straightforward. On one hand, collaboration is appealing because it entails the sharing of technical knowledge, associated risks and costs. Firm-university collaborations for example, are particularly advantageous in that respect. However, inter-firm innovative co-operation is fraught with additional considerations. The sharing of technical knowledge imposes real costs as it erodes a firm’s technological lead in a field and it involves sharing future profits. Therefore, collaboration with a competitor or potential competitor is not a
strategy that would normally be followed by a technological leader\textsuperscript{10}. Finally, where collaboration involves two or more vertically aligned firms, sharing knowledge about markets or supply factors is an important motivation.

Innovation is an integral part of a university’s mission; higher education is the natural place for innovation to occur. Etzkowitz (2003) contends that universities are well poised to generate innovations not least because of the high rate of flow of human capital (students), their technical and administrative support structures and the opportunities they provide for interdisciplinary combinations. Innovation in higher education is motivated by the prescriptions of research funders/contractors (i.e. an academic ‘profit motive’) and by a more elusive target of peer recognition. Peer recognition, and specifically its manifestation in the peer review process, bears a very pragmatic relationship to university matters. Peer review is often a criterion in research assessment linked to government funding. Nevertheless, universities are increasingly trying to diversify their sources of income, moving away from government funding mechanisms which are slow to materialise and modest in size (Etzkowitz and Leydesdorff, 2000). Sourcing contracts and collaborative agreements from firms can prove a more direct source of funding. Inventive efforts are also directed to solving practical problems. Thus universities seek links with firms for a multitude of reasons. Sharing costs is the most obvious one, but universities are also concerned with the commercialisation of innovative output, and can benefit from organisations with extensive market knowledge. The economic yields of

\textsuperscript{10} A conceivable exception would be a partnership entailing a technologically diversified firm leading more than one field and one or more technological leaders in one field. Under such a scenario collaboration may ensure that competitors are locked in a particular technological path thus denying them the chance to differentiate themselves.
knowledge are pursued both by means of collaboration with firms and by independently commercialising innovation (start-ups). Etzkowitz (2003) argues that as the result of increased university-firm collaborations, the university’s mission is expanding beyond teaching and research to include entrepreneurial objectives.

7. Conclusion

We conceptualise a NIS consisting of dynamic STI actors operating in the backdrop of a set of supportive social technologies. We have also highlighted the different roles STI actors perform within the system, thus enabling an understanding of their contributions to the system’s innovative capacity. Building on the NIS approach, the paper proposes a simple analytical framework emphasising the broad incentives of STI actors. The framework could act as a basis for specific case studies. The general two-step process stresses the dynamic nature of actors; their actions can only be channelled in the desired direction given certain rules as defined by institutions. Ultimately, the individual ways in which STI actors perceive benefits and costs determines what their actions are and the level of their commitment. Whereas innovation may be ‘easily’ induced within a competitive environment, competition may forestall collaborative arrangements. The understanding that innovative linkages hinge on a delicate confluence of interests enables an informed interpretation of organisational behaviour within a NIS. In the end, actors influence the structure of institutions, either by means of direct action (e.g. policy makers) or indirectly by means of technology lobbying. The above feedback mechanisms mean that in the long term the innovation system as whole is a dynamic entity.
References


