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MODELS OF INNOVATION

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Artikuloan zehar baldintza eta teknologia desberdinetan agerten diren berrikuntza-eredu desberdinen existentziaz jarduten da Zehazki, lau eredu desberdin aipatzen dira, honek sektoreko premiekin estu erlazionaturik daude, bata eta erabiltako teknologiekin berekin ere. Berrikuntzari dagozkion jarduera publikoak definitzerakoan, oso garrantzitsua da nolako ereduren gainean jardun beharra dagoen kontuan hartzea, ibilbide teknologiko jakineko sistemak eskuragarnenak gertatzen dira laguntza pol1lkoak definitzeko orduan, halakoen bilakaera aurrikusten ahaldelako. Aitzitik moldaketa-teknologiek hurbiltze publiko konplexuagoa eskatzen dute, zeren eta halakoetan aplikazio prozesuan berean gertatzen baita berrikuntza. Kasu horretan, erabiltzaileei zuzenduriko politiken beharrean gaude, l+G jarduerekiko laguntza edo teknologia transferentzia eraginkorrak ez direlako.

En este artículo se insiste en la existencia de diferentes modelos de innovación que aparecen bajo diferentes condiciones y tecnologías. En concreto, se mencionaron cuatro modelos diferenciados, que se encuentran estrechamente relacionados con las necesidades sectoriales y con las propias características de las tecnologías utilizadas. A la hora de definir las actuaciones públicas en materia de innovación es muy importante tener en cuenta sobre qué tipo de modelo se desea actuar. Los sistemas de trayectorias tecnológicas son los más accesibles para la definición de políticas de apoyo por el carácter predecible de su evolución. Por el contrario, las tecnologías de configuración requieren una aproximación pública más compleja ya que la innovación se produce en el proceso de aplicación. En este caso, se requieren políticas que se dirijan a los usuarios debido a que el apoyo a las actividades de l+D o a la transferencia de tecnología no resulta efectivo.

Tout au long de son expose, le rapporteur a insisté sur l'existence de différents modèles d'innovation qui apparaissent sous différentes conditions et technologies. De façon concrète, quatre modèles différentes, en relation étroite avec les nécessités sectoriales et avec les caractéristiques propres des technologies utilisées, furents mentionnés. Au moment de définir agissements publics en matière d'innovation, il estr très important de tenlr compte du type de modèle sur lequel on veut agir. Les systèmes de trajectoires technologiques sont les plus accessibles pour définir les politiques d’appui à cause du caractère previsible de leur évolution. Au contralre, les technologies de configuration requièrent une approximation publique plus complexe du fait que l'innovation se produit dans les processus d'aplication. Dans ce cas, on requiert des politiques qui s'adressent aux usagers vu que l'appui aux activités de l+R ou au transfer de technogie ne s’avère pas efficace.

INTRODUCTION

Innovation - «the process of bringing inventions into commercial use» (Freeman, 1982) -is an important subject, crucial to the health of modern economies. There has been much discussion in policy circles about how best to encourage innovation. For instance, the first UK Innovation Lecture, sponsored by the Royal Society, The Fellowship of Engineering and the DTI, featured Mr. Akio Morita, the Chairman of the highly innovative Sony Corporation (DTI, 1992). There has also been an emerging focus on the role of the user in technology development, with a long-running debate centring on the role of the market versus various forms of planning or organizationally mediated transactions (Williamson, 1975). These issues essentially relate to different forms of innovation process. There is no one process of innovation that covers every instance, but rather a variety of rather diverse forms. Clearly, the identification of the particular form operating in any given situation is crucial, especially since the different forms have quite different policy implications. This paper makes a start by identifying four distinct models of innovation and highlights the different conditions under which they are to be found.

At Edinburgh, we have been examining innovation processes with particular attention to the social influences on the development of technology, under the rubric of «the social shaping of technology» (Edge, 1986 and Edge and Williams, forthcoming). This approach complements and contrasts with the more conventional focus on the impact of technology on society. Two of us are developing a systematic framework for understanding the range of different technologies and how they variously come into being (Molina and Fleck, 1992 and 1995). We hope there by to devise practical analytical tools showing how policy makers and managements can improve their innovation practices. For example, by focussing on the necessity for feedback of various sorts under certain conditions, we have outlined how policy makers can harness and complement existing forces to enhance the innovation process (Fleck, 1990 and Molina, 1990). Innovation has been analyzed from many different perspectives: the history of technology; economics; sociology; management; policy studies; and technological practice itself. In this paper I adopt a synthetic approach and outline broad types or models of the innovation process, paying attention to the part played by feedback under different conditions, and indicating how these issues have been previously treated. I believe that useful insights are to be had from a more thorough going analysis which may help to provide objective means for distinguishing different types of innovation and for measuring the extent of different types of feedback. I hope, therefore, that this account of the rich empirical domain of innovation may alert interested parties to the fruitful opportunities for further modeling efforts. I hope also that it will help practical policy makers to appreciate the variety of different treatments possible and the conditions constraining the applicability of one approach over another.

MODEL 1: THE LINEAR MODEL

The linear model (Figure 1) perhaps reflects the intelligent lay person's view of how things are. The processes of creation, production and diffusion are seen as quite separate and distinct, and indeed are perceived as the prerogatives of different functions or even organizations: creation or invention being the exclusive concern of R&D departments; production, the business of manufacturing divisions, with some organizations (such as Sony for example) specializing in innovation, i.e., the first commercialization of a new invention; and diffusion being the concern of sales and sometimes constituting the main business of market-oriented organizations which focus on delivering high-volume low-price offerings (as, for example, with Alan Sugar's Amstrad).

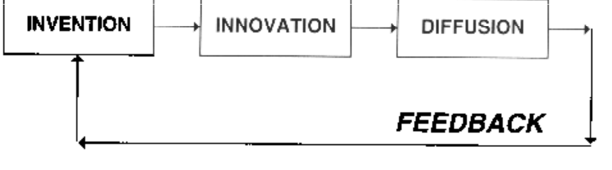

Figure 1. Schematic depiction of the linear model of innovation

In this simple model, there exists only the ultimate feedback mediated by successor failure in the market place. Such mobilised market forces can provide adequate information for the evolution of innovations in an essentially Darwinian process, provided an appropriate industry structure exists to channel and harness those variety matching forces. This model is a good approximation of the situation for consumer product innovation, where there exist mature, highly segmented and specialised industry structures, and products which are also highly discrete and generally highly standardised. Only a minimal role is played by consumers (the users in this case), primarily via their choices in the market place. However, even here linearity is mitigated by the rise of market research which seeks to enrich information feedback beyond pure price demand signals. This model is relatively readily quantified, and patterns of development over time (i.e., diffusion) can be captured in terms of product life cycles described by a variety of logistic or epidemiological models.

The linear model is widely thought to be more generally applicable. It is implicit, for example, in the recent influential analysis by Fukuyama (1992). He sees modern science (which he does not distinguish from technology) precisely in its capacity as a generator of consumer goods as the major driver of the world-wide trend towards the universal adoption of liberal democracy. It is also assumed in much governmental policy towards research and development. In particular, it is often argued that «spin offs» into wider civilian application will naturally flow from military research expenditure, although this is coming into question with the demonstrated superior performance of the Japanese and German economies, both of which focus effort more directly on civilian applications.

However, after considerable empirical research on innovation (Langrish et al., 1972; SPRU 1972; Gold et al., 1980; Sahal, 1981; Georghiou et al., 1986) it is now abundantly clear to innovation studies specialists that the linear model is strictly limited in its scope, and functions more as a «straw man» in critical discussions of technology development (Freeman, 1992). In practical terms it is applicable to situations characterised by a mature market structure and the presence of a scientific research intensive infrastructure, as is found in biotechnology and pharmaceuticals.

MODEL 2: EXPERT USER CONTRIBUTIONS

In certain situations, the inadequacies of the simple linear model are very apparent. Von Hippel (1976) showed that users are often the originators of innovations such as scientific instruments. In the creation of specialist tools for scientific, surgical or medical, or industrial use, the users play a crucial role - in many cases actually making the instruments or at least prototypes themselves, In such situations, the market information feedback loop of the linear model is replaced by direct user action,

Once such novel products have been developed, new Industrial structures may form over time to specialize in the development and production of variants. Contributions by specialist «expert users» continue to be an important input, transformed by the service capability of the sector into practicable devices. Such innovations are usually discrete and relatively small-scale in nature.

Von Hippel has sought (1988) to elaborate an economic theory explaining the conditions under which users contribute. In one of the most theoretically sophisticated analyses of innovation yet devised, he explains the propensity of users to contribute to innovation in terms of the basic economic rents they are able to derive from their inputs; i.e., he explains their involvement in terms of the economic system in which they are agents.

MODEL 3 TECHNOLOGICAL SYSTEMS AND TRAJECTORIES

Modern society, however, is not comprised of discrete technologies alone. Large technological systems, such as rail transport, electricity generation and distribution, and most recently telecommunications are typical. More compact, though no less complex systems such as modern aircraft, computers, and military weaponry are also common. Technological systems are too complex for any one institution to handle by itself. Extensive, mature and segmented industry structures have evolved - as the technologies themselves have evolved - and comprise many separate companies working in close complementary relationships. Complex systems of agreed standards ensure that the component innovations produced by different suppliers fit together to make up the overall systems.

Development in technological systems is constrained by the need for the whole complex to work effectively as a coherent whole, leading to «natural trajectories» of development (Nelson and Winter, 1982; Dosi, 1982). High-level system exigencies set problems which component innovators have to solve: as Hughes (1983) observes, «reverse salients» (i.e., critical areas in which lack of progress holds back overall development) attract the attention of would be innovators.

In such situations, very complex patterns of feedback exist at a variety of levels. These are articulated via evolved structures of industrial relationships (especially between user and supplier *institutions),* and via the recursive structure of engineering knowledge itself. Only at a very restricted local level does anything like the simple linear model apply. Under these conditions, events m the early history of an industry or technology may be crucial, and thus path dependencies become important for an understanding of development (Arthur, 1987 and 1990).

MODEL 4 CONFIGURATIONS AND INNOFUSION

Certain large-scale systems, however, are not characterized by any high-level dynamics of development, and therefore follow no clear trajectories. Rather, each installation is a more or less unique adaptation to the local contingencies of application. Extensive implementation effort (Leonard-Barton and Kraus, 1985; Voss, 1988) is consequently required to achieve successful operation. In such situations, often explicitly referred to as *configurationl* (Fleck, 1993), extensive user inputs at all levels are required, to such a degree that in-house development within the user organization is the rule rather than the exception, Organizationally-convoluted, company-wide information technology installations such as branch networks in banks, computer integrated manufacturing systems and computer aided production management systems, are prime examples, as are production lines which frequently have to be specifically reconfigured to meet the requirements of a particular production run.

Configurations are made up out of a wide variety of both technical components such as computer hardware or software, and non-technical components such as particular patterns of work organization or models of motivation (McGregor's theories X and Y and Ouchi's theory Z). Associated with the lack of a system-level long-term dynamic of development, there are emergent industrial structures in which the processes of invention, innovation and diffusion are not easily separable: suppliers are often at the same time important users, as was the case with industrial robots for instance (Fleck, 1984). Sometimes configurations turn out to have wider applicability beyond the specific contingencies which gave them birth In these cases, generic technological systems as already discussed above emerge, accompanied by an evolving industrial structure characterized by increasing separation between suppliers and users, a series of incremental improvements to the overall systems, and eventually the development of industry-wide standards.

But in many cases each configuration remains essentially unique, and the implementation effort required to achieve operation constitutes significant innovation in its own right (Leonard-Barton, 1988). In such cases the processes of invention, innovation and diffusion are collapsed together in a process of *innofusion* (Fleck, 1987), far removed from the simple linear model of innovation. Feedback is primarily through the internal learning processes involved in each exercise of implementation, rather than via transactions in the external market place. With the advent of home automation requiring considerable configurational effort by users (Cawson et al., 1990), these processes can involve domestic consumers, though in general they are more typical of various forms of process innovation.

With the advent of Multimedia, the internet, Electronic Data Interchange (EDI) and other forms of sophisticated information and telecommunication networks, a fifth emerging model can be detected: *network configurations.* This promises to be a crucial and distinct arena of development and policy concern. Here, renovations occur during diffusion as with configurations above. But, more radically, the potential Innovating users may be distributed over far-flung information networks linking geographically-separated sites. Potential innovations may emerge at any point in the network, and may involve multiple collaborating contributors distributed both in space and in time. There are likely to be, therefore, distinct policy challenges, including: the setting of infrastructural standards; the development of new forms of intellectual property right and associated policing systems; and the development of effective forms of filter to help identify the most effective specific innovations from the myriads of candidates on offer, especially where matters of public investment are concerned (as, notably, with basic educational materials).

SYNTHESIS AND POLICY IMPLICATIONS

If an inappropriate model of the underlying situation is applied, unsuitable and ineffective if not harmful policies may be followed. Indeed, the attempt by many organizations, usually relatively inexperienced with technology adoption, to straightforwardly *install* complex configurations, rather than recognizing the innovative implementation effort required, underlies the very high rates of failure typical of high technology adoption.

The above four models of innovation indicate idealtype boundaries of a graduated space of possibilities. Figure 2 indicates how they can be related in terms of three parameters: (a) the *maturity* of the technology and its associated-industrial sector; (b) the *complexity* of the technology - i.e., the extent to which it is systemic or discrete or stand-alone; and (c) the *degree of user involverment* (ratio of local process knowledge to generic specialist expertise). As discussed above, the type of user involvement (whether end-user, specialist-user or institutional-user) also varies across the delineated space. This schematic depiction is of course, capable of much further refinement and development, and is currently the focus of our research efforts.

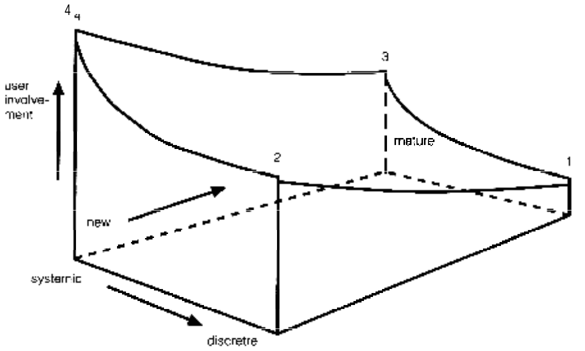

Figure 2. Schematic depiction of the space of broad types of innovation process.

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CONCLUSION

In the above I have outlined various models for the innovation process, ranging from a simple linear model to an extreme non-linear process, *innofusion.* In looking at the situation from a policy perspective:

(a) would it be possible to devise a unifying model or series of models for the different forms of innovation?

(b) would it then be possible to devise simple objective measures for distinguishing the various types of innovation described above, or even identifying other key types, in order to facilitate policy making?

(c) would it be possible at least systematically to set out the conditions under which one or other of the models are appropriate, in order to avoid calamitous misdiagnosis of policy treatments?

(d) would it be possible to simulate the results of policy initiatives in terms of such models, thus providing an alternative to conventional economic modeling which tends to be couched in terms of rather general economic variables and which lacks discrimination in terms of the specific innovation processes occurring?

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