2 Systems Failure and the Case for Innovation Policy

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2.1 Introduction

The topic of this chapter is the rationale for innovation policy in advanced market economies. Since innovation and its associates, invention and the diffusion of innovation, play such a central role in the performance of modern economies, indeed they constitute a defining element in the claim that they are knowledge-based, it is hardly surprising that this rationale should be an indispensable part of economic policy more generally. The Barcelona accord on research and development (R&D) spending[1] suggests how important this issue is for European governments, and raises the question of whether policy frameworks and instruments exist to reach the objectives of this accord. In particular, will it be possible to protect any sustained increase in innovation expenditures from the effects of diminishing marginal returns in the short run and in the long run[2]? We shall argue that new perspectives are needed on innovation policy if innovation is to be stimulated in Europe while avoiding the spectre of diminishing returns. We also suggest that the traditional rationale for innovation policy, market failure, is flawed in its understanding of the innovation process and, more fundamentally, flawed in is understanding of the wider process of competition in the modern world. The reasoning behind this claim is that processes of innovation depend on the emergence of innovation systems connecting the many actors engaged in the innovation process, and that these systems are essentially self organizing. Innovation systems do not exist naturally, but have to be constructed, instituted for a purpose, usually but not uniquely to facilitate the pursuit of competitive advantages by firms. To

[1] To raise European R&D to 3% of GDP by 2010 with at least two-thirds of this contributed by industry.

[2] Diminishing returns to the economic payoff, not diminishing returns to the growth of scientific and technical knowledge.

anticipate the conclusion, innovation policy should be about facilitating the self-organization of innovation systems across the entire economy, not only in 'new' sectors. In sustaining this claim, we shall argue that innovation is one element, perhaps the most important, of the general class of investment activities in an economy, that it is complementary with other classes of investment undertaken by firms and other organizations, and that it requires much more than expenditure on science and technology for its realization. A functioning science and technology (S&T) policy is in the first instance a stimulus to invention, in the process it facilitates innovation, but the connection between the two is essentially a matter of investment, of present commitment in anticipation of future return, and it is equally important that policy promote the general process of investment if innovation is to flourish. Thus R&D spend may be a necessary underpinning for innovation but it is certainly not sufficient, other complementary investments in skills, productive capacity and markets are also required. As an innovation policy lever on its own, S&T policy leaves much to be desired. Moreover, all investment is uncertain in its consequences, but investment in innovation is particularly prone to the unexpected and the unintended consequences of action, precisely because innovation is a major source of business uncertainty. In exploring the limits of the market failure doctrine we also draw attention to the general limitations of an equilibrium approach to the analysis of innovation and competition and suggest that an adaptive evolutionary process view is a far sounder framework for understanding and policy guidance. Innovation involves the growth of multiple kinds of knowledge including knowledge of how to organize and knowledge of the market opportunities, and these different kinds of knowledge, complementary to scientific and technological knowledge, are gained inseparably from the competitive market process. Innovation is a route to competitive advantage, but the converse is true also, that competition shapes the innovation process; the two phenomena are inseparable. In developing the argument, we will amplify the idea of innovation systems but not from a national perspective. Rather we emphasize the local character of innovation systems and the need for policy to deal with the issues surrounding their birth, growth, stabilization and, if necessary, decline. National arrangements influence the ecology of organizations and the institutional rules of the game that enable innovation systems to be formed but innovation systems are not intrinsically national. Indeed a central implication of the unification of the European market is that 'local innovation systems' will cross national boundaries, with the prospect that national policies develop inconsistencies that are inimical to innovation performance. Thus, we argue that a systems failure perspective allied with notions of evolutionary competition will enable governments to form and implement

effective policies. Since innovation requires the development of new knowledge, typically within firms but more broadly in contributing innovation systems, the stimulus of innovation cannot ignore the conditions that facilitate the growth of knowledge and the communication of information. This epistemic dimension turns out to be of quite crucial importance in the innovation systems failure perspective. Finally, we say little directly about existing policies and instruments and direct the reader to a recent paper by Luke Georghiou for a detailed elaboration and evaluation of European level policies[3].

2.2 Attributes of the Innovation Process

We begin with a brief statement of the relevant attributes of the innovation process. Innovation is, first and foremost, a matter of business experimentation, the economic trial of ideas that are intended to increase the profit of or improve the market strength of a firm. This occurs in two broad sets of conditions, defined by innovation in existing enterprises and innovation by new enterprises, and the two are quite different contexts for innovation experiments. Innovation, in this regard, is the principal way that a firm can acquire a competitive advantage relative to its business rivals. As a process of experimentation, a discovery process, the outcomes are necessarily uncertain; no firm can foresee if rivals will produce better innovations nor can it know in advance, even when all technical problems are solved, that consumers will pay a price and purchase a quantity that justifies the outlay of resources to generate a new or improved product or manufacturing process. This is not a matter of calculable risk, for probabilities cannot be formed in respect of unique events, events that change the conditions under which future events occur. There is an inevitable penumbra of doubt that makes all innovations blind variations in practice, and the more the innovation deviates from established practice the greater the fog of irresolution. Perhaps the fundamental point is that innovations are surprises, novelties, truly unexpected consequences of a particular kind of knowledge-based capitalism. This does not mean that innovation is irrational behaviour, firms are presumed to innovate in ways to make the most of the opportunities and resources at their disposal; however, neither the opportunities nor the resources available can be specified with precision in advance. Innovation is a question of dealing with the bounds on human decision making, it is to a substantial degree a matter of judgment, imagination and

[3] See Raising EU R&D Intensity, European Commission, 2003, the report of an expert group under the chairmanship of Professor Georghiou.

guesswork, and the optimistic conjecturing of future possible economic worlds. Consequently, policy instruments must be subject to the same penumbra of doubt in terms of their effects on the innovation process; there will be unanticipated consequences of innovation policy and great difficulty in tracing cause effect relationships in the evaluation of policy.

The second attribute of the innovation process is the necessity for new beliefs and knowledge to emerge before innovation is possible. Moreover, innovation requires the drawing together of many different kinds of information, on the properties of a device or method, on the way to organize production and the perceived needs of the market. It is the combination of these elements that matters and the only locus of combination in capitalism is the firm[4]. Thus while many agencies may provide information valuable to the innovation in question, only the innovating firm can combine them into a "plan" for innovation. Neither universities, nor government laboratories nor knowledge consultancies, which play an increasingly important role, have this final combinatorial responsibility, in this, the for-profit firm is unique. The corollary of this is that multiple kinds of knowledge are typically required to innovate and many of the sources of this knowledge will lie outside the firm, which has to extract the necessary information and integrate it into its own knowledge (Gibbons et al. 1994). Consequently, the external organization of the firm and the management of its internal processes are essential elements in the innovation process and this insight is the foundation of the innovation systems perspective.

The third attribute of innovative activity is its embeddedness or more accurately its instituted position in the competitive market process. Not only do firms innovate to generate market advantages relative to their perceived rivals, so that the functioning of markets shapes the return to innovation, but market processes and their wider instituted context of law, custom and regulation greatly influence the outcomes of innovation and the ability to innovate. Innovation is not a matter of market processes acting in isolation but of the interdependence between market and non market, and public and private spheres of action. Moreover, the instituted context is broadly based, for example, the way users respond to an innovation and the ability of a firm to raise capital and acquire skilled labour and components necessary to an innovation are essential market process determinants of innovation activity. Yet, the fundamental test for successful innovation is not that it works but that it is profitable *ex post*, and this is a matter of market process. If markets are inefficient and distorted, this can only harm

[4] Broadly defined to include not for profit organizations that produce goods and services, such as hospitals, as well as the traditional for profit business organization.

the innovation process and when incumbents and conservative users unduly control the relevant markets, the effect will be similar. It follows that competition policy and an efficient markets policy, more generally, are necessary elements in innovation policy. Conversely, a pro-innovation policy is perhaps the most effective contribution to a strong competition policy.

Since innovation entails the acquisition of new knowledge, we need to be clear what is meant by knowledge, and the processes by which it is generated and diffused. Knowledge has a unique property, it always and only ever exists in the minds of individuals and it is only in individual minds that new innovative concepts and thoughts can emerge. This is fundamental, it is why we recognize the entrepreneur and the prize-winning scientist – they are different as individuals – and from it follows the fact that knowledge is always tacit it is never codified as knowledge. What is articulated and codified is information but information is only ever a public representation of individual knowledge, sometimes virtually a perfect representation, but in many significant cases not. As Polanyi (Michael not Karl) expressed it, we know more than we can say and can say more than we can write. Since economic activity in firms and beyond depends on the ability of teams of individuals to coordinate their actions, it follows that processes must exist for correlating the knowledge of the individual members so that they understand and act in common. In regard to innovation, the internal organization and business plan of the firm are the primary means of coordinating information flow and turning individual knowledge into the necessary hierarchy of understanding and actions. It may be helpful to conceive of the organization of a firm is an operator, a local network of interaction through which what the individual members of the firm know is combined to collective effect. The spread of understanding in correlated minds is essentially a social process of human interaction, however, a chief consequence of information technology is that information can be communicated at a distance and this makes possible the inclusion of a firm in wider, less personal networks, including the scientific and technological networks that communicate almost exclusively in written form. To call these knowledge networks may be understandable, but it is a mistake. The relevant networks are information networks, perhaps better expressed as networks of understanding, and could not be otherwise, and their significance is in shaping what individuals in firms, and other organizations transmit and receive as information. It is not that information is transmitted with error, it may be, rather, what matters is that information may legitimately be 'read' by recipient and transmitter in different ways. The interpretation of the message is not in the message but in the different minds of the parties concerned (Arthur 2000). Indeed the growth of knowledge de-

pends on this possibility of divergent interpretation of the information flux. All innovations are based on disagreement, on a different reading of information much of which is currently available in the public domain. Thus, the prior knowledge state influences what is 'read' and what is 'expressed' and, as Rosenberg (1990) made clear, firms have to invest in their own understanding if they are to participate effectively in innovation information networks and this is why it is necessary for them to conduct their own R&D[5]. Thus while information is a public good, in the sense of being useable indefinitely, it is not a free good, scarce mental capacity must always be engaged to convert it to and from private knowledge (Cohendet and Meyer-Kramer 2001). Here we find one of the principal sources of variation in the innovation process, innovations are conceived in individual minds and these minds differ. It only needs a moment's reflection to recognize that if all individuals held the same beliefs there could be no growth of knowledge and no innovation and thus the beliefs in question could not have emerged in the first place. Idiosyncracy, individuality, imagination are the indispensable elements in the innovation process and the way innovation policy is framed must recognize this fact, indeed, without them entrepreneurship would not be recognizable. The obvious corollary to the policy process is that innovation cannot be planned from on high, it emerges from below.

Scholars interested in innovation have for many years drawn upon the useful Polanyian (1958) distinction between tacit and codified knowledge, the former embodied in human skill and practice, the latter in material form. Tacitness is presented as a reason why information does not flow freely, while codification, is a process to make information public. Thus, Callon (1994) is quite right to point out that the limits to excludability depend upon the way in which information is embodied in different communication media, and that access to any particular knowledge depends upon complementary assets being accumulated to give the capability to maintain and use knowledge based statements. However, it is important to recognize the point that the division of knowledge into mutually exclusive categories, codified and tacit, does not uniquely reflect properties of the knowledge itself. Rather, it is in part an economic decision dependent on the scale on which the information is to be used and the costs of codification. It is thus

[5] It is said that the British system of Industrial, Cooperative Research Associations, set up primarily in fragmented industries, failed to raise innovation performance, precisely because their target firms did not invest in acquiring their own capacity to understand the research and development carried out on their behalf.

inextricably linked with the division of labour in the economy more widely, as I shall explain below.

The distinction drawn here between information, knowledge and the understanding necessary for teamwork and cooperative endeavour, also bears on the question of property rights in knowledge and the assessment of the system of protection of intellectual property. Quite obviously, in the light of the above, knowledge is always proprietary it never leaves the minds of individuals, it is only its expression as information in a public domain that raises questions of intellectual property. Thus the oft-expressed view that secrecy is a very effective, perhaps the most effective form of protection. Where this is unavoidable, and in respect of product innovations it is nearly always so, patents protect the economic exploitation of the idea, but not its exploitation in a wider sense. Namely, the quid pro quo for economic protection is the placing of an accurate description of the invention in the public domain thus opening the possibility that others are guided to the same effect, and by a different route. This is the technological price the inventor pays for the economic right of exploitation, and rightly so. It should also be remembered that patents protect the exploitation of the knowledge in the invention and that this is only part of the knowledge required to innovate. The firm with the excellent patent record is not necessarily the firm best able to turn those inventions into profitable innovations.

A fourth implication for the innovation process is that the systemic, emergent nature of group understanding leads directly to the basis of innovation systems. There is an increasingly elaborate division of labour in the generation of knowledge, to use an old economic concept, the division of knowledge labour is becoming increasingly 'roundabout' in nature. Since Adam Smith, scholars have recognized that the knowledge contained in any economy or organization is based on a division of mental specialism. It is not simply that the division of labour raises the productivity of the pin maker, it also raises the productivity of the 'philosopher and man of speculation' and greatly augments the ability to generate knowledge in the process. When this division of labour is not contained within the firm we have the conditions for an innovation system to emerge and the necessity for the coordination of the divers minds within that system. Innovation systems are the necessary consequence of this division of knowledge; and these systems do not arise naturally, they have to be organized and are not to be taken for granted. This self-organization process is a central concern of innovation policy from a systems failure perspective. Innovation systems are, in Hayekian terms, a form of spontaneous order, that is to say they are self-organizing. Perhaps the most obvious characteristic of modern economies is the distributed nature of knowledge generation and the consequent

distributedness of the resultant innovation processes across multiple organizations, multiple minds and multiple kinds of knowledge (Coombs et al. 2004). As a system, what matters are the natures of the component parts, the patterns of interconnection and the drawing of the relevant boundaries and each of these aspects forms a dimension of innovation policy, as we explore below.

Fifthly, and finally, it is helpful to group the factors that influence the ability to innovate into four broad categories, perceived opportunities, available resources, incentives and the capabilities to manage the process. In principle, we could imagine policy levers for each of these elements, but what matters is that all four need to be addressed if policy is to be effective. Thus, increasing the resources devoted to innovation is likely to run into rapidly diminishing returns if new opportunities are not perceived or if the management of innovation is weak and poorly connected with other activities in the firm (Carter and Williams 1957)

With these aspects of the innovation process in mind we turn now to an assessment of the traditional market failure rationale for policy and then contrast it with the systems failure perspective before drawing general conclusions for policy.

2.3 The Limits of Market Failure

The development of an economics of information and knowledge in the 1960s led scholars to the realization that knowledge and information are not normal economic commodities but possess attributes that do not make them natural candidates for market exchange (Nelson 1959; Arrow 1962). The market failure doctrine and the rationale it provides for innovation policy have followed from these insights. Central is the idea that markets in relation to knowledge and information have an inherent tendency to produce socially inefficient outcomes, inefficiencies that provide the justification for failure correcting public policies. The private hand is not guided to produce and use the socially optimal amount of knowledge, and the optimizing policy maker is justified in corrective intervention through the joint provision of resources and incentives at the margin. This has proved to be a powerful set of ideas for shaping policy debate, particularly concerning the public support of university based science and technology that are far from market application. I shall argue that it has been a far less useful means for designing specific innovation policies in relation to private firms. The reason is clear, the idea of a perfectly competitive allocation of resources (the doctrine of Pareto optimality) on which the idea of

market failure is premised is a distorting mirror in which to reflect the operation of a restless capitalism. This doctrine seriously misreads the nature and role of competition in modern societies through its failure to realize that capitalism and equilibrium are incompatible concepts and that innovation and enterprise preclude equilibrium.

Why does the market failure doctrine fail in respect of innovation? The reasons are hidden within the properties of a perfectly competitive economy. For its realization not only must all agents be denied the power to influence prices of products and productive factors, there must also be a complete set of markets that values all consequences of all economic action in the present and in the indefinite future. In general, the set of possible markets is incomplete and serious problems follow. The consequences of action that are not priced in the market are called externalities and, from an innovation perspective, the most significant externalities relate to imperfect property rights in the exploitation of knowledge. If the works of the inventor can be copied without cost, others may turn invention into innovation, and erode the incentives to invest in invention. This has long been recognized as a justification for patent and copyright systems and rightly so. Nonetheless, the practical implications of intellectual property protection are less straightforward.

The problems are two-fold. It is not information spillovers *per se* that damage the incentive to invest in knowledge production but a presumption of instantaneous and complete spillover, an unlikely state of affairs for reasons which become clear below[6]. Absent this and the existence of many practical ways that firms have developed for protecting knowledge acquired privately, and it becomes clear that inventors and innovators may still gain an adequate return from their investments without patent protection. Secrecy and a short product lifecycle, are familiar examples and help explain why patent protection is only considered significant in a small number of industries, those with high invention costs and long lead times to market. Secondly, this doctrine is far too negative, not all information spillovers are between direct competitors or diminish innovation opportunities. The difficulty arises from thinking that all firms are the same, losing sight of the fact that they read the information flow with different 'minds'. Spillovers can, and generally will, have positive benefits in stimulating the differential creation of new knowledge, which should not be underestimated, indeed, this is why patents are designed to put inventive ideas in the

[6] I note in passing that what is spilt is information (messages) not knowledge. The knowledge content of any information flow is, of course, notoriously unpredictable as any university examiner knows only too well. That this is so is essential to the emergence of novelty.

public domain. There is no reason why an alert firm should not gain more than it loses from the unplanned flow of information and so enrich its innovative capacity. In this regard, information spillovers are to be encouraged and one might expect firms to try to manage this process through links with other knowledge generating institutions, which is precisely what we observe in practice[7]. What is interesting about the idea of property rights in commercially valuable knowledge is that they sit side by side with very imperfect property rights in economic activities more generally[8]. Copy my invention and I can pursue you in the courts. Make a better, but unrelated, equivalent and there is nothing we can do except compete. Indeed if it were otherwise, it is difficult to see how capitalism could have been the source of so much economic change and development. This means of course that competition is a painful process. Investors, whether their assets are in paper titles or human skills, are ever open to the erosion of their worth by innovations made by others, this is why innovation driven capitalism is, from a welfare point of view, an uncomfortable restless system. The fact that, on average, innovation enhances the standard of living should not blind us to this fact and to the inherently uncertain, potentially painful nature of innovation related economic processes. From a policy viewpoint, one immediate implication is that the scope of patents should not be drawn too broadly, for this simply limits the ability of others to creatively explore the design space which any patented invention has placed in the public domain. A world with no spillovers simply restricts, perhaps makes impossible, the wider and deeper growth of knowledge. Thus, broad patents have the potential to damage the creativity of the capitalist model (Merges and Nelson 1990).

Externalities do not exhaust the idea of missing markets. Perhaps more important is the absence in general of futures markets to guide investment decisions. All innovations are investments, activities that require current outlay in advance of the economic return. Yet the markets to trade these future outputs, by establishing the price today for an activity to be sold say a year hence, exist only for a narrow range of standardized commodities that are broadly speaking unaffected by the prospect of innovation. In the absence of known prices, the only recourse is to substitute the judgment of entrepreneurs. This uncertainty is intrinsic to the market process, for the

[7] Hence the increasing volume of work which points to the role of knowledge spillovers in productivity growth. Cf. Griliches (1998) for an authoritative treatment.

[8] It is worth noting that competition authorities in the UK have taken a dim view of firms that refuse to grant licences to exploit their patents and of attempts to use licences to distort the competitive process.

most significant sources of uncertainty relate not to whether it will rain a year from today, but whether others will have developed superior innovations by that date. It is not the game against nature that matters but the capitalist game of innovation, of rival against rival. In modern capitalism, genuine uncertainty is 'built in', as it were, and its consequences for the willingness to invest in innovation are far more difficult to cope with, because innovations, like all discoveries, are unique events for which the probability calculus is an inappropriate method of analysis. Much decision making about knowledge creation is at root an act of faith, it is a matter of the conjecture of imagined future worlds with necessarily unpredictable time delays between knowledge creation, application and market testing (Loasby 1999). Keynes's much ignored notion of animal spirits is certainly appropriate as a route to understanding innovation in capitalism. Moreover, it is not at all obvious that the process of accumulation of scientific or technological knowledge is any less hazardous than the accumulation of market knowledge (Callon 1994). A central implication of this theme is that investment becomes impossibly difficult in perfectly competitive markets as pointed out by Richardson (1961). Current market prices do not convey the information required to invest since they do not convey information about the investment plans of rivals. Consequently, firms seek other ways to tacitly or explicitly coordinate their activities whether complementary or competitive and these necessitate deviations from the atomistic competitive ideal. Although Richardson directed his analysis at investment in productive capacity, it applies equally well to investment in innovation, and one would predict a need for market imperfections if such investment is to be stimulated. One consequence of all this is that innovation processes are mediated by a range of non-market methods, primarily involving information networks and other forms of arrangement between organizations and individuals, procedures that build confidence and trust and work to limit the damaging consequences of uncertain, asymmetric information. These arrangements are precisely contrary to the idea of competition between isolated, atomistic, independent firms. Without market power, innovation becomes an unlikely occurrence, and collaborative R&D arrangements, for example, are one way of dealing with the implied coordination failures.

However, it is not at all obvious from a wider view that the missing markets constitute market failures in the narrow sense that we have used so far. Uncertainty and asymmetries in knowledge are direct consequences of a market process in which innovation is the driving force for competition. Without innovation, it is possible that a richer ecology of futures markets would come into existence, but this is not the market capitalism we know, it is rather a picture of a stationary state. It is surely perverse to label as

market failures phenomena that are integral to the competitive market process and which give modern capitalism its unique dynamic properties. Nor is there any obvious way that policy could 'correct' for lack of futures markets, they are simply intrinsic to the process of innovation and economic change. The fundamental fact is that profits follow from the deployment of ideas that others do not have, with the consequence that the whole system dynamic depends upon the generation of unquantifiable uncertainty and asymmetries in information. One cannot sensibly argue that the economy would perform better if innovation related uncertainties were reduced, for the only way to reduce these uncertainties is to reduce the incidence of innovation and thus to undermine the mainspring of economic progress. This does not deny that radical uncertainty can be a justification for policy intervention. Indeed the rationale for the public support of fundamental research in science and technology lies in the fact that the links between these general categories of knowledge and market exploitation of specific innovations is often so tenuous that private firms would, quite legitimately, find no justification for investing in these kinds of knowledge. Even here, the matter is not clear-cut. For by no means all university research in fundamental science and technology is funded by government, and of that which is, a proportion is directed at meeting the mission objectives of government agencies in such areas as defence or health. Conversely, non-academic organizations carry out a substantial portion of work on fundamental science and technology; indeed large private firms, usually multinational firms, can often boast far more advanced research facilities than can universities[9].

Having dealt with the problem of missing markets, consider next the idea that perfect competition requires an absence of market power, in particular that each firm be small relative to the scale of market to make this possible. It is recognized that a major reason this condition will not be achieved is the presence of some form of increasing returns in the use of resources. Yet, fundamental to the economics of knowledge production and dissemination is the fact that the exploitation of all knowledge is subject to increasing returns: the fixed cost of producing an item of knowledge can be spread over a greater volume of output, as it is used more widely and more intensively in the production process. Since one cannot innovate on the basis of a fraction of a technology or a quarter of a scientific fact, there is necessarily an indivisible cost of creating the complete set of knowledge behind an innovation. Consequently, the costs of exploiting an

[9] Narin et al. (1997) find that of the US scientific papers cited by US industrial patents only 50% came from academic sources while 32% came from scientists working in industry.

innovation fall with the scale of exploitation, precisely the condition that removes the possibility of perfect competition. Furthermore, every investment in innovation now requires its own expected minimum scale of exploitation if an adequate return is to follow. The result of these considerations is the complete inability of the perfectly competitive model to provide guiding innovation policy principles in a world where firms are required to innovate in order to compete (Stiglitz 1994). The overhead innovation costs that firms must incur unavoidably mean that their behaviour will at best be imperfectly competitive and that there will be systematic and uneven deviations between prices and marginal production costs across the economy. The only way the fixed costs of knowledge production could be recovered, independently of prices and outputs, would be for public laboratories to develop that knowledge, or for all private research and development expenses to be fully subsidized from the public purse. This is not a model for innovation likely to commend itself outside of very special cases such as metrology and public technical standards (Tassey 1992).

Nor do missing markets and market power exhaust the difficulties in using perfect competition to reflect modern capitalism. There is also the, so-called, public good problem. All knowledge and information has the intriguing property that it is used, but not consumed in its using and that, once discovered, it is in principle useable by any individual on any number of occasions to any degree. In the terminology of economics, there is non-rivalry and non-excludability of knowledge. This terminology is not well chosen in relation to knowledge and information. We argued in the previous section, that knowledge is only ever private and is certainly excludable by choice of the knowing individual. It is a representation of that knowledge, information that is placed in the public domain, but this is only accessible to everyone in principle. In practice, and as a direct consequence of the division of knowledge labour, to gain knowledge from information requires prior background knowledge to read that information and this knowledge has not been acquired without opportunity cost. There is much more to the transfer of knowledge than the costs of communication in the narrow sense. In many cases the interchange of knowledge requires communication between correlated "like minds" only open to those who have acquired comparable abilities to understand the significance of new scientific and technological information. Self-exclusion follows from an inability to make the necessary background investments; information may be "free" but the ability to extract knowledge from it is not and it is the knowledge that matters for innovation (Mowery and Rosenberg 1989; Rosenberg 1990; Hicks 1995; Veugelers 1997).

To a degree, these different dimensions of market failure are interrelated. The public good aspect of information links directly to information spillovers and the externality problem. The fact that knowledge can be used repeatedly connects to the increasing returns dimension of the exploitation of information, whether in producing goods or, more significantly, in the further production of knowledge. In each case, we are led to deviations from the perfectly competitive market ideal, but it is not at all obvious that affairs can otherwise be arranged. All economies are knowledge based and the problems of the economics of knowledge are not an optional extra, they are intrinsic to the nature of a capitalist, market economy. When we turn to innovation policy, it is apparent that we are in difficulty in basing the rationale on a model of perfect competition. Leaving aside the well recognized imperfections that governments can be subject to when they intervene, backing the wrong horse too quickly or maintaining programmes long after the evidence against continuation is conclusive (Walker 2000), it is clear that market failure as a policy framework leaves much to be desired (Metcalfe 1995a,b). Market failure is a general rubric not a recipe for stimulating individual innovations. The logical underpinning it provides tells us nothing about the precise design of policy instruments, or their appropriate method of implementation or the firms that are most appropriately in need of support in their attempts to innovate. Is the focus to be on new knowledge, new skills or new artefacts? Is it to be concerned with design, with construction or with operation? Is it to focus on the creation of innovation or upon the diffusion of innovation? The answers to these questions could generate very different policy initiatives that bear no particular relation to specific innovation activities. The information to provide the answers is simply not available to the policy maker, nor for that matter to anyone else. The market failure framework, despite its formal elegance, is an empty box. In the presence of the apparent market distortions in relation to knowledge and information, there is no warrant for the idea that piecemeal policy can improve economic welfare, the world is simply too complicated to avoid these problems of the second best. Perhaps the problem is deeper, in that the issues of uncertainty, "spillovers", increasing returns and "publicness" are not failures at all but vital elements in the evolutionary process that is capitalism. This thought takes us to the nature of competition and the idea of innovation systems and their failure as the basis for policy.

2.4 Innovation Systems and the Competitive Process

The foundation of an alternative approach is that of competition as an evolutionary process not as a state of equilibrium. In this perspective innovation plays the central role as the source of the differences in firm behaviours that give rise to competitive advantages. Rivalry depends on differential behaviour and these differences are resolved into differences in profitability and the consequential differences in the relative growth of rival producers. If markets are working well from an evolutionary perspective, firms with superior competitive knowledge and thus practice are able to grow at the expense of less competitive rivals. This is the central dynamic of evolutionary competition as a dynamic discovery process. All that competition requires is rivalry, and two firms can be as competitive as many and have a greater impact on the long run capacity to use resources efficiently. In such a view, the role of markets is to coordinate and evaluate rival business conjectures and so guide the economic change we (partially) measure in rising standards of living. This involves adaptation to new opportunities, new needs and new resources and market institutions are to be judged not by the canon of Pareto optimality, but by their openness in stimulating innovation and adapting to change (Metcalfe and Georghiou 1998).

Thus, the central weakness of the market failure approach is not its lack of precision, but its attempt to establish a policy perspective within the confines of the static equilibrium theory of markets and industry. The market failure arguments identify significant features of the production and use of knowledge, but these features have their full impact only in relation to the dynamic nature of the competitive process. Economic progress depends on the ongoing creation of private, asymmetric knowledge, knowledge that is sufficiently reliable and defendable to justify the original investment, yet has prospective returns that are not only uncertain to the investor but create uncertainty in complementary and competitive fashion to other investors. The imperfections identified in the market failure approach are to be viewed now in a different perspective, as integral and necessary aspects of the production and dissemination of knowledge in a market economy. From this perspective, it is surely perverse to call them imperfections or market failures. This is, of course, not a new point: for those who have studied Schumpeter they are the natural features of an economic process driven by creative destruction. Another way of putting this is to say that without asymmetries of knowledge and the correlated uncertainties and indivisibilities the competitive process has nothing with which to work. The quasi-public good nature of knowledge, indivisibility

and increasing returns, the inherent uncertainties of creative, trial and error processes and the imperfect nature of property rights in knowledge are essential if market capitalism is to function. They are not imperfections to be corrected by policy.

Several important themes now fit into place in a way that is impossible with the market failure doctrine. First and foremost among them is entrepreneurship a phenomenon, which has no meaning in economic equilibrium of any kind. Entrepreneurs introduce novelty into the economy, they disrupt established patterns of market activity, they create uncertainty and they provide the fuel that fires the process of economic evolution. The fact that the framework of perfect competition cannot incorporate the entrepreneur is a telling statement of its inapplicability to an innovation driven economy. Secondly, the reward for entrepreneurship is the differential economic reward that comes from introducing economic improvements relative to existing practice. Such abnormal rewards are not the consequence of market imperfections, they do not necessarily reflect the undesirable use of market power; they are instead the rewards for superior performance and are to be judged as such. It is a view that abnormal profits are the socially undesirable consequences of market concentration that is the real Achilles heel of the market failure approach and which denies it anything useful to say in the appraisal of knowledge-based, innovative economies.

Thirdly, this perspective of competition and innovation as a coupled dynamic process provides us with a framework to formulate innovation policy. Innovations create the differences in behaviour, which we identify as competitive advantages, and the possibility of competition provides the route and the incentives to challenge established market positions. Moreover, to the extent that market institutions function properly, firms with superior innovations will command an increasing share of the available scarce productive resources, the process that is the link between innovations in particular and economic growth in general[10].

This suggests that innovation policy and competition policy are complementary, indeed that a pro-innovation policy may be the surest form of competition policy, and that its broad purpose is to ensure that conditions remain in place for the continued creation and exploitation of asymmetries of knowledge. In truly competitive markets, all established positions are

[10] As an aside here, we note that competition is not to be judged by market structure. Two rivals may compete far more intensively than many. The way to judge the efficacy of competitive arrangements is to consider the degree to which rivals can gain market share at the expense of each other and the degree to which they are innovating in the pursuit of competitive advantage.

open to challenge and it is this link between innovation and competition, which has proved to be the reservoir of economic growth. Thus, capitalism is necessarily restless, occasionally kaleidoscopic, and competition is at root a process for diffusing diverse discoveries, the utility of which cannot readily be predicted in advance. The market mechanism is a framework within which to conduct innovative experiments and a framework for facilitating economic adaptation to those experiments[11]. The key issue, therefore, is how this competitive process interacts with the conditions that promote innovation.

2.5 Increasing Returns, 'Roundabout' Knowledge Production and Innovation Systems

We have referred already to the inevitable presence of increasing returns in a knowledge-based economy, the fact that the returns to investments in innovation increase with the scale of their exploitation. That this rules out a perfectly competitive allocation of resources is well understood but there is much more to the phenomena than is suggested by this partial and static perspective. The point is a more general one. As Adam Smith understood so clearly, increasing returns applies to the generation of knowledge as well as to its exploitation precisely because of the increasing specialization of bodies of knowledge and knowledge generating institutions. What we are observing in modern innovation systems is the increasing roundaboutness of production, not of material artefacts but of knowledge in general (Young 1928).

It can be argued that two features shape the modern innovation process; namely, increasing complementarities of different kinds of knowledge together with increasing dissimilarity of these bodies of knowledge, a reflection of an increasingly fine division of labour in knowledge production (Richardson 1972). Innovating firms need to draw on and integrate multiple bodies of knowledge, whether scientific, technological or market based, produced in an increasing range of increasingly specialized contexts[12]. At the same time to understand the significance of and contribute to

[11] This theme of the experimental economy has been particularly important in the work of Eliasson (1998). It has an inevitable Austrian hue, that markets are devices to make the best of our limited knowledge (Rosenberg, 1990).

[12] Cf Grandstrand et al. (1997) for evidence that large corporations are increaseingly diversified in the technological fields which they employ, and more diversified relative to their product fields. See also Kodama's (1995) work on technology fusion.

advances in these various kinds of knowledge is increasingly beyond the internal capabilities of the individual firm. Consequently, firms must increasingly complement their own R&D efforts by gaining access to externally generated knowledge and learn how to manage a wide spectrum of collaborative arrangements for knowledge generation (Coombs and Metcalfe 2000) The consequence is that innovations take place increasingly in a systemic context with respect to the use of new technologies and their generation. How they occur is a question in the coordination of the division of labour in innovation systems. This is a central difference from the market failure approach, in which innovation is treated as a problem internal to the firm. Instead, we have to enquire how groups of organizations are coordinated to give innovation processes a systemic dimension.

The essential point is the distinction made above between private knowledge and public understanding. All new knowledge arises only in the minds of individuals and if it is to have a wider effect it must not only be communicated to other minds but these minds must absorb it and reach similar understanding of the phenomena in focus. In short, knowledge must be correlated across individual minds. This is essential for any joint action and it is essential to the further growth of knowledge, as enquiring minds respond to the information that constitutes the testimony of others. The consequence of this is that what is understood is systemic, covering multiple individuals, it is combinatorial and it is emergent. Not only is understanding complicated, in the sense of the multiplicity of minds involved, it is also dynamically complex, in the sense that it its development generates novelty in unpredictable and unintended ways; this is one foundation for the uncertainty that underlies innovation-led capitalism. Capitalism is a restless evolving system precisely because its knowledge foundations are restless and adaptive too. The process of correlation of knowledge is complicated further by the fact that individuals typically express and communicate their knowledge in the context of the organizations of which they are members, and the rules and routines of these organizations shape the interplay of information both within and without that organization. Thus, all knowledge systems are constructed around multiple minds in multiple organizational contexts and here we should distinguish invention systems from innovation systems proper. The science and technology systems composed of universities and public and private research laboratories are primarily invention systems[13] and, as Schumpeter insisted, invention is conceptually distinct from innovation. Innovation systems depend on additional sets of actors in relation to the availability of productive

[13] See, in particular, Carlsson (1995,1997) for a detailed exposition of the related concept of technological systems.

inputs, the design of organization and the engagement with customers and they depend on the unique role of the firm to combine the knowledge of these elements to achieve innovation. The knowledge and ability to organize a productive activity, to identify markets and to mobilize resources, are essential elements in the innovation process; for innovations are not only about the generation of knowledge, but also the economic application of knowledge. Thus, innovation systems are embedded in the market process, with customers, suppliers and even rivals on occasion, acting as important system components (Lundvall 1986, 1992). Markets are the context in which resource problems in relation to innovation are solved and in which innovation opportunities are identified.

However, systems are not defined only in terms of their components, in this case knowledgeable individuals in organizations; the nature of the system also depends on how these individuals are connected by flows of information and the purpose that lies below the flow of information. That correlation of knowledge requires communication of information indicates the importance of the connections in the innovation system, and the need for these connections to change as the innovation problems change. In many important cases, communication requires personal interaction and its correlates of trust and empathy between the individuals. In other cases, particularly in regard to science and technology, communication can rely on communication technology so that much of the information considered reliable comes from minds that are distant and anonymous. Indeed, it is these non-social forms of communication, information technology broadly defined, that have transformed knowledge generation. By permitting connection between a far greater number of minds than is possible through personal interaction alone, information technology has been of vital importance not only to correlate knowledge more widely but also to stimulate the further growth of private knowledge within innovation systems.

Yet science and technology systems are not innovation systems, the latter are far more focused in scope and directed to business objectives, that is to say they are focused around very specific, local problem sequences reflecting the proprietorial concerns of the innovating firm. The most appropriate way to conceive of these systems is that they self-organize and that private firms take the lead in stimulating the self-organization of the knowledgeable minds in the system. This means that innovation systems are locally dynamic entities, they are born, grow, stabilize and ultimately decline and fail and that the basis for the dynamic of self-organization is the evolution of the particular innovation problem sequence. Part of the dynamic of system change is that the growth of knowledge depends on disagreement across individuals and the fact that the solution to one problem typically opens up new problems that may require different kinds of

knowledge in their solution. As Cohendet and Meyer-Kramer (2001) are right to point out, innovation systems operate as recursive trial and error processes for stimulating the growth of knowledge in relation to specific problems. The consequence of this is that as the problem sequence evolves so too do the components and connections defining the particular innovation system. Thus, there seems great merit in seeing innovation systems as a form of self transforming, spontaneous order that interacts with the process of market competition outlined above. Perhaps the key point to note is that innovation systems are the constructed bridges between invention systems and market systems (Carlsson et al. 2002).

We can summarize the focus of this perspective in terms of the development of the innovation infrastructure in the economy; an information infrastructure that facilitates the intercommunication of existing knowledge and mutually shapes the future agendas of different organizations around innovation problem sequences. In short innovation systems are devices to correlate knowledge and in the process advance knowledge in regard to specific innovations. It is an infrastructure to correlate knowledge through communication and to coordinate access to complementary kinds of knowledge required to innovate and it is more than the infrastructure for science and technology (Edquist 1997; Carlsson 1997; Nelson 1993). Many organizations are involved, private firms operating in market contexts, universities and other education bodies, professional societies and government laboratories, private consultancies and industrial research associations, but only the first of these is in the unique position to combine the multiple kinds of knowledge to innovative effect. Between them there is a strong division of labour and, because of the economic peculiarities of information noted above, a predominance of coordination by networks, public committee structures and other non-market mediated methods (Tassey 1992; Teubal 1996). The division of labour is of considerable significance for the degree to which the different elements of the system are connected. Different organizations typically have different cultures, use different "languages", explore different missions, operate to different timescales and espouse different ultimate objectives. Consequently, information is "sticky", it is partially unintelligible, it does not flow easily between different institutions or disciplines and thus it is difficult to correlate knowledge to the desired degree. Therefore, there is a major problem to be addressed in seeking to achieve greater connectivity of information flow processes[14].

[14] Cf. Andersen et al. (1998) and Green et al. (1998) for further elaboration of the systems perspective. Also see Edquist (1997) for a quite excellent overview of the current state of the art.

One influential strand of thinking in this area has been to emphasize the national domain of the science and technology infrastructure, and rightly so (Freeman 1987, 1994; Lundvall 1986; Nelson 1993)[15]. Policy formulation and implementation is essentially a national process, reflected in language, law and the nature of national institutions and conventions. However, there are good reasons to elaborate the national perspective both downwards and outwards. It is important to recognize that different activities have different supporting knowledge infrastructures so that a sectoral innovation system perspective becomes essential[16]. This is simply one way of recognizing the specificity of the broad innovation opportunities facing firms (Carlsson 1995; Malerba et al. 2004). On the other hand, it is clear that the sectoral infrastructures frequently transcend national boundaries; a firm may draw on several national knowledge ecologies in its pursuit of innovation depending on where the knowledgeable individuals are located. Gibbons and colleagues (1994) draw attention to the emerging characteristics of new models of knowledge production, a view that fits exactly with the view that innovation requires many kinds of knowledge for its successful prosecution. What they term "mode-2" knowledge is produced in the context of application, seeks solutions to problems on a transdisciplinary basis, is tested by its workability not its truthfulness and involves a multiplicity of organizational actors, locations and skills. Together this entails a distributed system for innovation with no one-to-one correspondence with traditional national or sector boundaries.

To summarize the argument thus far, while nations and sectors contain the ecologies of knowledgeable individuals usually within organizations these ecologies do not constitute innovation systems. Systems require connections as well as components, and it is the formation of the connections that is the necessary step in the creation of any innovation system. Innovation systems do not occur naturally, they self-organize to bring together new knowledge and the resources to exploit that knowledge, and the template they self-organize around is the problem sequence that defines the innovation opportunity. Hence, innovation systems are emergent phenomena, created for a purpose, they will change in content and pattern of connection as the problem sequence evolves, and they are constructed at a mi-

[15] Carlsson (2004) has found 750 studies of innovation systems published in the past 15 years, half of which relate to national innovation systems.

[16] There is a growing literature on regional innovation linkages in which an attempt is made to correlate innovation clusters with the processes of university based scientific activity. See Varga (1998) for a review and empirical study of linkages in the USA. The paper by Malerba et al. 2003 is a comprehensive summary of these sectoral perspectives.

cro scale. Within these networks, firms, the unique organizations that combine the multiple kinds of knowledge to innovative effect, play the key role in the self-organization process. Science and technology systems, networks and communities of practice, are necessary parts of the innovation networks but they are not sufficient.

2.6 Policy for Systems Failure

Reflection on the above leads to a new rationale for innovation policy one that subsumes science and technology policy within its remit; this is the rationale based on system failure. It takes for granted the significance of an economic climate, with low real interest rates and stable macroeconomic and monetary conditions that encourages investment in all forms. Here the primary role of the state is to facilitate the emergence of innovation systems. In so doing it takes responsibility for the ecology of public organizations and institutions that facilitates business experimentation but recognizes that without the necessary interconnections the ecology is not a system. Since competition depends on innovation and innovation depends on the emergence of distributed innovation systems, it is clear that this provides an interesting alternative to the market failure perspective on innovation policy[17]. We call this the system failure perspective. The state is not promoting individual innovation events in this view; rather it is setting the framework conditions in which innovation systems can better self-organize across the range of activities in an economy. Moreover, whereas the market failure approach leads to instruments that allocate resources to firms in the form of R&D grants or tax incentives, the systems failure approach leads to instruments that enhance innovation opportunities and capabilities. Because systems are defined by components interacting within boundaries, it follows that a system failure policy seeks to address missing components, missing connections and misplaced boundaries. Each of these is a problem associated with the division of knowledge labour and the increasingly roundabout knowledge production processes, and the location of relevant knowledge in specialized organizations.

The availability of components is none other than the availability of knowledgeable individuals that can be allocated to an innovation process either in a firm or some other knowledge organization. The supply of knowledgeable minds to which innovating firms have access is perhaps the most crucial aspect of the innovation systems approach and of innovation

[17] Cohendet and Meyer-Kramer (2001) use the phrase knowledge oriented policies to capture much of what is meant here.

policy for it is individuals within organizations who are the elemental components of innovation systems. There availability is, in part, a general question about the wider education and capability formation process but, more specifically, it concerns the quality of the science and technology system in a country. "Are there sufficient knowledgeable individuals in relation to multiple branches of knowledge, in place or in training, on which firms can draw to solve innovation problems?" This is the question that governments need to answer. Capabilities may be weak in some areas and non-existent in others and government has a role to ensure that a sufficiently rich knowledge ecology is available from which innovation systems can be assembled.

The availability of knowledgeable individuals is a necessary but not sufficient condition for the emergence of innovation system. In relation to some kinds of knowledge, the required information may be in the public domain in published form, papers, reports, patents, in which case the transfer process is effectively anonymous and impersonal. In many other cases, the information has to be elicited in some form of implicit or explicit contractual arrangement through a direct process of personal interaction. This is the social network basis for innovation systems. In all cases, the knowledge of the existing members of the firm is crucial to the ability to identify and absorb external information (Cohen and Levinthal 1990) If the individuals are not employed by innovating firms, then only an external transfer arrangement can communicate what they know to the firm and here there is a wide spectrum of possibilities, not only in relation to the external organization of the firm, but also in relation to the external organization of other knowledge holding organizations. All the organizations in a systemic context must be consciously outward oriented if system failure is not to occur. Self-organization can fail because the different individuals are within organizations whose agendas and practices are misaligned in respect of a particular innovation problem sequence. The rules that shape each knowledge organization are often effective barriers to communication with other organizations, a natural consequence of the different purposes of each organization and the primary need to focus on internal procedures. Thus, firms and universities are remarkably different kinds of knowledge organizations, they reflect a natural division of specialization and each is to be presumed appropriate to task; consequently, it would be as inappropriate to make universities operate like firms as it would be to attempt the converse. These differences are a potent source of innovation system failure, and the systems failure policy response to this problem is the design of effective bridging arrangements, notionally between different organizations, but ultimately between individuals.

In the past two decades, policy makers in the USA and Europe have followed such an approach without perhaps realizing its systemic foundations. The current emphasis on collaborative research programmes including firms, customers, suppliers and universities, the incentives to set up science parks or university incubators, the emphasis on cluster development programmes, the establishment of technology transfer offices in universities, the funding of major industrial R&D programmes within university laboratories and the intensive national efforts at Foresight activity are important examples of bridging mechanisms[18]. Each of these is a device, whether conscious or not, to deal with a systemic failure in the innovation process, a failure in the self-organization of connection and interaction. Bridging processes are not designed to generate passive flows of information but to engage all the parties in an alignment of knowledge generating and information sharing processes, that is, to create a distributed innovation system (Coombs, Harvey and Tether 2004). Distributed innovation processes are partnerships with reciprocal obligations as well as collaborations in pursuit of shared objectives. Since firms are likely to be the lead partners in defining the innovation problem sequences it is vital that they have the internal capabilities to interact with other knowledge agencies. There is consequently little point in governments supporting S&T in universities and public laboratories in the hope that this will lead to greater wealth creation unless private firms throughout the economy have the R&D capacity to ask the right questions of external individuals. This is one reason why tax credits for R&D, for example, may be a useful complement to an innovation systems policy.

However, the fact that problem sequences evolve implies that the related innovation systems need to evolve also. Policy can only facilitate, it cannot design because design is always emergent. The members of a system and their connections will change over time and eventually any system becomes redundant as its underlying innovation opportunities are exhausted. It is important, therefore, that innovation systems are seen as transient, that they have useful lives, and that they need to be dissolved when their purpose is fulfilled. In innovation policy as elsewhere, there is an ever present danger of preserving arrangements designed and instituted for yesterday's problems not the problems of the future (Walker 2000).

Within this systems failure framework, there is a predominant emphasis on supply side measures directed primarily at the invention system with little attention given to the wider market context of the innovation process. From a policy viewpoint this misses an opportunity for a complementary

[18] See the 'Georghiou Report' (footnote 2 above) for a comprehensive summary of such policy initiatives in Europe.

demand side approach that focuses on the procurement of innovation through public expenditure programmes. To recognize this is to recognize the significant role that users and consumers play in the innovation process, they are not obviously the passive elements described in the Schumpeterian approach. In respect of health, education and transport as well as defence, public agencies account for substantial proportions of national expenditures and even a small proportion of this funding could be used to contract for innovation and provide a degree of market stability. As in the case of the USA, with the SBIR programmes, public procurement can also be used to stimulate innovation in SMEs, since they face greater difficulties in participating in innovation system arrangements by virtue of their limited managerial resources.

2.7 Conclusion

In this chapter I have reviewed recent developments in innovation policy thinking and attempted to view them through the lens of new developments in our understanding about innovation systems and the processes that form them. Here the fundamental insight is the experimental, evolutionary nature of a market and network economy. As Schumpeter aptly observed capitalism works by means of creative destruction, and we have suggested that innovation systems are created and destroyed as part of that process, a process that is played out on a global scale nowadays. Patterns of international competition are ever changing and an advanced country must be ever aware of new opportunities and threats if its standard of living is to be sustained. Central to this must be the rate of innovative experimentation and I have suggested that a consistent thread to policy has emerged in the past twenty years based around a distributed innovation systems perspective and innovation-led competition. In this new approach, it is the transient, institutionalized basis of innovation that is the focus of attention, rather than expenditure on research and development. I have called this the system failure perspective. From a political point of view this raises an interesting problem. Experimental economies experience many failures as well as successes, blind variation means that a great deal of effort is wasted, but this is a necessary part of the process of knowledge accumulation. As a general rule concerns for public accountability within the political process do not easily accommodate the notion of misdirected effort, which often appears with the benefit of sufficient hindsight. Governments must learn to be experimental and adaptive too, just like the firms and other organizations whose innovative efforts they seek to jointly

stimulate. In this way they can expect to facilitate the self-organization of innovation systems that underpin the future self-transformations of the economy on which standards of living will continue to depend.

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